FINAL REPORT

PROJECT A-691

DETERMINATION OF ELECTRICAL CONDUCTIVITY OF MATING SURFACES——A LITERATURE SURVEY

W. E. WOOLF

Contract No. NAS8-5292

Prepared for
George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Huntsville, Alabama

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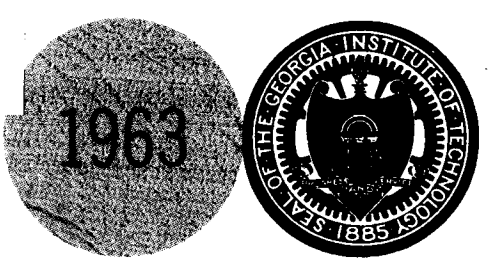

Engineering Experiment Station
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By

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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FOREWORD

This is the final report prepared under Contract No. NAS8-5292 for the Quality Assurance Division, George C. Marshall Space Flight Center, Huntsville, Alabama. The report was prepared in the Engineering Experiment Station, Georgia Institute of Technology. The work was conducted under the general supervision of D. W. Robertson, Head, Communications Branch. In addition to the author, the principal participants in the performance of the literature search and in the preparation of this report were R. E. Meek, Research Engineer; L. W. Ross, Assistant Research Engineer; and D. L. Box, Graduate Research Assistant.

Respectfully submitted,

W. E. Woolf
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ABSTRACT

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This report covers a literature survey on the subject of electrical impedance between mating metallic surfaces. A bibliography containing 477 entries is presented; in most cases an abstract is included. The report contains a brief analysis or survey of results related to topics such as measurement of low impedance bonds, physical and chemical factors affecting the bond, changes of bond impedance with time, and lesser known methods of determining bond characteristics.

TABLE OF CONTENTS

This report contains 158 pages.

I. INTRODUCTION

This report presents the results of a literature survey and an analysis of the survey on the electrical conductivity of mating metallic surfaces. The objective of this effort was to determine the extent to which various parameters influence the direct current resistance and the alternating current impedance of a bond and to determine the current status of satisfactory bonding techniques and satisfactory methods of measurement of their impedance.

The literature survey was based principally on the following abstract sources:

1) ASTM Bibliography and Abstracts on Electrical Contacts, 1835-1951 and supplements thereto for the years 1952 through 1961. (No articles published prior to 1940 have been included in view of the great development in measurement techniques during the intervening years.)
2) Science Abstracts B, volumes 57 (1954) through the June issue of Volume 66 (1963).
3) Electronic Technology Abstracts and References (and its predecessors), Volumes 29 (1952) through 38 (1961).
4) A card bibliography requested from the Defense Documentation Center.
5) Scientific and Technical Aerospace Reports.
6) Technical Abstract Bulletin for 1961, 1962, and for 1963 through the August 1 issue.

Partial surveys were also made of certain technical journals or their subject indices; the results indicated that the abstract sources were adequate and that it was not necessary to search the original literature. The results of the literature survey are presented in the form of a bibliography, with abstracts, in Section II of this report. The articles are arranged alphabetically by

authors. The source from which each abstract was obtained is indicated at the end of the abstract, except in those cases in which the abstract was prepared by a member of the research group.

In Section III information derived from sources listed in the bibliography on a limited number of particularly pertinent topics, is summarized and discussed. The final section, IV, presents the general recommendations and conclusions of the research group resulting from this literature search.

The abstracts in Section II have been reproduced in this report with the permission of the editors and publishers of the respective publications. We gratefully acknowledge this kindness on their part.

II. BIBLIOGRAPHY

1. Aas, H., "Electrical Resistance Measurements on Various Types of Pipe Unions Used in Water Supply Systems," Elektrotek. Tidsskrift 74, 371-4 (Sept. 15, 1961). In Norwegian.

   Corrosion of water supply pipes in Oslo caused by leakage currents prompted a series of measurements on the electrical continuity of the pipe systems. One system investigated comprised a 470 m long loop with several outgoing pipelines. Screwed 6 in. dia. unions were used. The resistances measured at the pipe joints were 60-80Ω and in some cases of the same order as the resistance to earth of the system. Measurements on unions with lead inserts and with bolted flanges gave good results, resistances of the order of $0{\cdot}2\text{-}12 \times 10^{-3}\Omega$ being obtained (Science Abstracts).

2. Adams, R. T. and Horvath, A., "Broad-Band Reflectometers at High Frequencies," Elect. Commun. 32, 118-25 (June, 1955).

   If the voltage and current with their relative phases at any point in a transmission line can be sampled, the sample outputs can be combined in various ways, to give a standing-wave monitor, a power meter, or bridges for the measurement of resistance, reactance or phase. The special form of instruments described uses reactive coupling elements in order to achieve broad-band working. Notes are given on the construction of the circuit elements used. (Science Abstracts).

3. Aerospace Technical Intelligence Center, Wright-Patterson Air Force Base, Ohio, Electrical Contacts (Selected Articles). Translation no. MCL-480 from Elektricheskiye Kontakty, 79-95; 255-296, 1958. AD-257 134 (2 Nov. 60). 71 pp.

   Contents:
   The role of an electrical contact in the process of forming a welded joint; Alloys of noble metals for electrical contacts carrying very low currents and voltages; Alloys for electrical contacts with low contact resistance; The use of new materials for sliding contacts operating in self-synchronizing synchronous transmission systems; Survey of experiments and research on contact materials made of precious metals; The state of production and normalization of contacts and contact materials made of precious metals. (ASTIA Technical Abstract Bulletin).

4. Akerloff, G. C., A Bibliography of Chemical Reactions in Electric Discharges, Mellon Institute of Industrial Research, (1950). 240 pp.

5. Albin, A. L., "Shielding Efficiency of Electrically Conductive Protective Coatings for Magnesium and Aluminum Surfaces," Symposium Digest of Fifth National Symposium on Radio Frequency Interference, (June 4 and 5, 1963)

   Measurements were made of the bond impedance between aluminum and magnesium surfaces, either bare or treated with one of several chromate conversion finishes. The measurements were made in a special test fixture with a fixed applied pressure (50 lb/in^2) and at d.c., 150 kc or 3 Mc.

The correlation between joint impedance and shielding efficiency at magnesium mating surfaces was examined with a welded enclosure having a removable cover plate. Various finishes were applied to the mating surfaces which could be clamped together with or without a gasket. The author concludes that the bond impedance measurements were not sufficiently sensitive to distinguish between satisfactory and unsatisfactory shielding efficiency.

6. Allen, Joseph A., High Frequency Impedance Measurement of Bond Straps. Signal Crops Engineering Labs., Coles Signal Lab, Fort Monmouth, N. J., AD-148 842 (19 Nov. 1951).

   This report presents only the results of insertion loss measurements on round and flat stranded wire bond straps. Frequency range was from 0.15 to 30 megacycles. Connection impedances to the straps were not evaluated.

7. Allen, R. K., "Design and Analysis of an Unplated High-Pressure Limited-Area Bolted Electric Joint: A Method of Calculating Various Components of Joint Resistance," Trans. Amer. Inst. Elect. Engrs. III 78, 1047-53 (1959).

   Joint resistance may be divided into three major components: (1) resistance of the basic metal or ordinary ohmic or body resistance; (2) resistance resulting from surface tarnish films trapped between the members of the joint (film resistance); (3) resistance due to the converging of the lines of current flow as they pass through the small "true conducting" area of the joint (constriction resistance). Difficulties involved in assessing the quality of a joint include the effect of tarnish films and the presence of uneven protuberances or asperities. A joint having unusual geometry is described which gives superior performance over a flat-on-flat point on tarnished conductors because the high-pressure scrubbing section resulting from the unusual geometry converts a greater portion of the load-bearing area. This design gives additional flowed-wiping action, thus lessening film resistance, and the geometry is such that constriction resistance is also reduced. A method of calculating joint resistance is given in an appendix. (Science Abstracts).

8. Allison, J. and Benson, F. A., "Measurement of Impedance and Attenuation of A Cable Through An Arbitrary Loss-Free Junction," Proc. Instn. Elect. Engrs. 105B, 487-95 (Sept., 1958).

   Considers the problem of finding the impedance and attenuation of a transmission line when measured through an arbitrary loss-free junction. Several possibilities for the exact determination of impedance in such a case are mentioned, and the results of tests carried out to determine the usefulness and accuracy of certain methods are presented. Some information is also given on the experimental accuracy of the well-known circle-diagram technique for determining transmission-line characteristics. (Science Abstracts).

9. Alsberg, D. R., "A Precise Sweep-Frequency Method of Vector Impedance Measurement," Proc. IRE 39, 1393-1400 (Nov., 1951).

   If a two-terminal network is connected in series or shunt with a line joining a source and detector of known impedances, the network impedance

can be deduced from the insertion loss and phase shift. As these quantities can be recorded automatically it is possible to use a sweep-frequency method. Apparatus having a range 0.05-20 Mc/s is described and the results quoted of measurements made on piezo-electric devices and transmission lines. A simple grid added to the Smith chart simplifies the calculations.

10. Anderson, D. G., "Corrosion," J. Electronics and Control 5, 443-56, (Nov., 1958).

A brief general survey of the main causes of corrosion in industry is given and the more important methods of protecting against corrosive environments are described. The paper is by no means intended to be an exhaustive treatise on this vast subject; its primary object is to point out some of the more obvious pitfalls to be avoided and to assist those engaged in production processes who may not be familiar with electrochemical phenomena. (Science Abstracts).

11. Anderson, J. C., "Surface Impedance Measurements at V.H.F.," Electronic Radio Engr. 36, 56-60 (Feb., 1959).

The high-frequency surface impedance of a conducting material may be measured by use of a coaxial transmission line. The method described does not require the use of a calibrated r.f. meter, and employs a specimen in the form of a disc. Measured values of impedance may be used to yield the v.h.f. permeability of a ferromagnetic specimen, and results are given for measurements on pure nickel. (Science Abstracts).

12. Anderson, Jack R., Research and Development Work Relating to Cable Connecting Networks for Micro-Modular Equipment. Stanford Research Inst., Calif., Rept. no. 12 (Final). AD-264 060 (1 July 61) 82 pp.

Surface treatments, which decrease friction and wear through boundary lubrication, on connector mating parts offer a promising approach to improve the reliability of dry circuit, micromodule connectors. Because of the necessity of maintaining connector resistance in the milliohm range, the surface treatments investigated were (with one exception) monomolecular-like films of long chain organic compounds containing polar end groups. (ASTIA Technical Abstract Bulletin).

13. Anderson, Jack R. and Saunders, John B., Stable Sliding Connector Contacts. Stanford Research Inst., Menlo Park, Calif., Semi-annual technical rept. no. 2. AD-299 985 (1 Dec 62) 28 pp. (ASTIA Technical Abstract Bulletin).

14. Anonymous, "Infrared--a Modern Approach to Quality Control," Int. Electron. 4, 16-18, 27 (Dec., 1962).

Describes the use of infrared camera for inspection of electronic components and circuits.

15. Anonymous, "Admittance Bridge," Engineering, Lond. 189, 224 (Feb. 12, 1960); Engineer, Lond. 209, 307 (Feb. 19, 1960).

The type TF 978 admittance bridge, manufactured by Marconi Instruments Ltd., U. K., incorporates a high stability servo-controlled conductance balance

system. The instrument is particularly suitable for measurements on unbalanced aerial systems, coaxial transmission lines, and distributed components in general, and operates in the range 30 to 300 Mc/s. (Instrument Abstracts).

16. Anonymous, "Heavy Current Busbars," Elec. Times 114, 3-5 (July 1, 1948).

A unique installation, for electrotinning steel strip, requiring busbars to carry 20-30 ka. d.c. is described. Reasons for choosing Cu and not Al are given. Heat dissipation, jointing, allowance for expansion, flexible connections, ect., are also dealt with. (Science Abstracts).

17. Anonymous, "Junctions in Aluminum Cable," Light Metals 5, 388-395 (October, 1942).

Illustrated description and test results of various types of mechanical jointing devices for aluminum conductors, based on recent German publications. (Science Abstracts).

18. Anonymous, "Accurate Measuring Techniques for R-F Voltage," Electronics 34, 90 (May 12, 1961).

Accurate r.m.s. voltage measurements are possible using thermal voltage convertors. They can also be used to determine quickly the effect of frequency on other r.m.s. instruments. Accuracy is at least 0·1% up to 10 Mc/s and 0·2% at 30 Mc/s. For 50 V, a v.h.f. 5mA thermoelement is used with a series impedance mounted axially inside a brass tube with brass end discs. With higher voltages two inner brass tubes, adjustable to minimize distributed capacity, are used. They are useful in transfer techniques where d.c. input voltages are used to give the same reading as the a.c. voltage which is under test. The d.c. input voltage can then be read very accurately by any appropriate measurement. (Science Abstracts).

19. Anonymous, "Solid Aluminum Cables," Electrical Times 139, 125-9 (Jan. 26, 1961).

It is stated that the ease of handling and manipulation of these cables can effect installation cost economies, as compared with other types, of 66% and more. They are suitable for direct burial in the ground, pulling into ducts or aerial suspension. Several jointing techniques are available, all of which, it is claimed, have been successfully tried out. Special fluxes have also been developed to suit particular conditions. A range of jointing accessories and fitments specially designed for these cables are given in tabular form. It is stated that no special problems arise in jointing to conventional types. Although p.v.c. insulated cables have known temperature limitations, they are able to withstand the severest mechanical stress conditions likely to be encountered in practice. Detailed illustrations are given of the jointing procedure. (Science Abstracts).

20. Anonymous, "Copper and Copper Alloys: A Survey of Technical Progress During 1960. Copper Development Association," Metallurgia 63, 132-6 (March); 175-84 (April, 1961).

Extraction and refining, foundry practice, metalworking techniques, mechanical and physical properties, electrical properties and applications, mechanical, chemical and marine engineering corrosion, finishing and plating, joining, powder metallurgy, physical metallurgy and metallography,

analysis and testing, building and plumbing, copper salts and compounds, (Science Abstracts).

21. Anson, W. J., "A Guide to the Use of the Modified Reflectometer Technique of V.S.W.R. Measurement," J. Res. Nat. Bur. Stand. 65C, 217-23 (Oct.-Dec., 1961).

The theory of the modified reflectometer technique of measuring v.s.w.r. at microwave frequencies is discussed briefly, the operational procedure is outlined, and selected results are given of an unpublished error analysis. Much of the theory and procedure has been published in isolated papers. This paper unifies those details essential to the use of this technique and includes procedural suggestions that have grown out of extensive experience with the technique. The error analysis provides the means to evaluate the accuracy of any particular measurement made with this system. (Science Abstracts).

22. Atkinson, P., "Solderless Joints--The Technique of Wire Wrapping," Brit. Commun. and Electronics 10, 288-9 (April, 1963).

In many equipments, but particularly those subject to vibration hazards in service, soldered and screwed connections are no longer acceptable. The performance and manufacturing advantages of solderless wrapped connections are compared with those of more traditional methods. (Science Abstracts).

23. Axworthy, F. R., "Industrial Electrical Measuring Instruments. A Review of Progress," Proc. Instn. Engrs. 105B, 404-14 (Sept., 1958).

Discusses in some detail, magnetic and insulating materials, long-scale instruments, typical movements, live-conductor testers, and portable instruments. (Science Abstracts).

24. Ayers, E. W., Aspinall, E. and Morton, J. Y., "An Impedance Measuring Set for Electrical, Acoustical and Mechanical Impedances," Acustica 6, 11-16 (1956).

An impedance to be measured is compared with a reference impedance of similar nature by connecting each in turn to a source of adjustable strength. If the internal impedance of the source is constant, the vector ratio of the unknown and reference is the ratio of the changes in stimulus required to restore the source to short-circuit conditions, or the reciprocal of this ratio if the source is restored to open-circuit conditions. (Science Abstracts).

25. Azbel', M. Ya., "On the Theory of Skin Effect in Metals," Zh. eksp. teor. Fiz. 32, 1259 (May, 1957).

26. Azbel', M. Ya. and Kaner, E.A., "Anomalous Skin Effect with Arbitrary Collision Integral," Zh. eksper. teor. Fiz. 29, 876-8 (1955). In Russian.

At temperatures large compared with the Debye temperature the collision integral can be written in a precise form involving the relaxation time. In a previous paper an expression for the surface impedance of a metal exhibiting the anomalous skin effect has been derived for these conditions. At lower temperatures an arbitrary form has to be assumed for the collision integral and the present paper shows that this assumption does not change the form of impedance previously derived. (Science Abstracts).

27. Bachel, J., Lenz, K. L. and Zinke, O., "The Effective Resistance of Laminations, Strips, Wires, Tubes and Coils of Different Materials in the Frequency Range Between 10 c/s and 100 Gc/s," Frequenz 9, 401-6 (Dec., 1955).

The materials considered include Ag, Cu, Al, Pb, brass, C, Ge and Fe. A graph is given of the effective skin depth against frequency for these materials. The essential parameter for calculation is resistance per square and curves are given for materials of thickness 0.1, 0.3 and 1.0 mm. There is a short table showing the effective electrical thickness of round, tubular, strip and helical conductors and some results reported of measured and calculated Q-values for coils in the range 10-25 Mc/s. (Science Abstracts).

28. Bailey, J. C., "Bolted Connections in Aluminium Busbars," Engineer 199, 551-4 (April 22, 1955).

The performance of bolted connections in busbars has frequently been criticized because of the tendency observed in some instances for high resistance to develop with the passage of time. This review of the data available indicates the essential factors in good jointing technique: and covers both laboratory studies and practical experience over 30 years. Recommendations are given for the essential requirements for achieving bolted busbar joints of satisfactory low resistance and good stability. (Science Abstracts).

29. Bailey, J. C. and Gregory, P., "Fundamentals of Jointing Processes for Aluminium," Aluminium and Its Alloys. Aluminium Development Association, 39-58 (1958).

Surveys those jointing processes that are generally applied to aluminium in fields other than electrical engineering, with the object of exploring their application to the jointing of electrical conductors. This unorthodox approach to jointing problems is deliberate and is justified at the present stage; it reveals that aluminium can be jointed as readily as copper, and in some instances more readily. No difficulty is experienced in soldering aluminium cable sheaths. Attention is drawn to the advantages of fusion welding, resistance welding, and pressure welding, which yield permanent low resistance joints, and to brazing which is equally suitable. It is also suggested that crimped joints involving deformation of the conductor are particularly appropriate to aluminium, whilst methods familiar to copper such as bolting, clamping and soldering can be successfully applied with appropriate modifications. (Science Abstracts).

30. Baimakoff, Y. V., "Resistance of Contact Between Metals, and Between Metals and Carbon Materials," Engineer's Digest (April, 1947).

In two tables is given the effect of temperature and pressure on the contact resistance. Heating for 120 hours to 300 C. caused as much as 40 times increase for the pair steel-aluminum but a drop of resistance to 1/4 for brass-brass, and to 1/6 for brass-carbon and steel-carbon, to give a few examples. The tests were done at pressures of 150 and 600 kg. per sq. cm. (ASTM Bibliography and Abstracts on Electrical Contacts).

31. Barnett, J. and Burrows, D., Interference Problems Due to Structures in High RF Fields. White Electromagnetics, Inc., Bethesda, Md., Rept. no. C-24-F. AD-299 257 (1 Feb 63).

32. Barwell, F. T., "Wear of Metals," Journal Inst. Metals 86, 257-269 (Feb., 1958).

Significant factors are: speed and load, geometry, lubricant, surface roughness, nature of oxide films, metallurgical structure, presence of abrasive matter, and corrosive environment. The mechanism of wear, pitting arising from rolling contact, scuffing arising from sliding contact, fretting corrosion due to vibratory motion, and the effect of oxygen in friction and surface damage during simple sliding are discussed. (Battelle Technical Review).

33. Beattie, J. R. and Conn, G. K. T., "Surface Resistance and Reactance of Metals at Infrared Frequencies," Proc. Inst. Radio Engrs. 44, 78-81 (Jan., 1956).

At frequencies $> 10^{12}$ c/s surface reactance cannot be neglected when measuring surface resistivity by a reflection method. Measurements of surface reactance and resistance for metal films and surfaces (prepared in different ways) have been made in the frequency range $2.5 \times 10^{13} - 1.5 \times 10^{14}$ c/s by methods previously described (Science Abstracts 2628-9A, 1955; Phil. Mag., Vol. 46, 222-34, 235-45, Feb., 1955). It was found that by choosing suitable values of the conductivity and relaxation time the measurements on Cu, Ag and Al could be made to exhibit a frequency dependence very close to that predicted by a simple theory of electron relaxation (Science Abstr. 1032 A, 1949; Proc. Roy. Soc. A, Vol. 195, 336-64, Dec., 1948). Results for Ni diverged somewhat from this law for reasons which are discussed. In all cases the conductivity was less than the predicted d.c. value and in general temperature coefficients were also smaller than expected. Surface roughness of approximately 10^{-6} cm would be sufficient to account for these effects. (Science Abstracts).

34. Beattie, R. W., Forshaw, G. and Leney, E. N., "Design, Material and Performance of Plugs and Sockets for Electronic Switching Applications," Proc. Instn. Elect. Engrs. 109B, 102-10, 122-6 (June, 1961).

From experience gained with plugs and sockets used in electromechanical telephone-switching apparatus and further experience and their use in association with electronic equipment, the necessity to improve their performance and reliability soon became apparent. Extensive research into the study of materials has led to the formation of a test specification which has the objective of determining plug and socket reliability for an anticipated usage of 30 years. This specification is given in an Appendix. Two designs satisfying this specification are outlined. (Science Abstracts).

35. Beck, A. C. and Dawson, R. W., "Conductivity Measurements at Microwave Frequencies," Proc. Inst. Radio Engrs. 38, 1181-9 (Oct., 1950).

Because of the skin effect, the surface condition of conductors becomes very important in determining attenuation at microwave frequencies. This has been investigated by measuring small wire samples at ~9000 Mc/s. A sample of the wire to be measured is inserted in a metal tube to form the centre conductor of an open-ended coaxial line. The ratio of the peak frequency to the half-power bandwidth of this coaxial-line resonator, measured with the aid of an oscillographic display of its amplitude/frequency characteristic, gives its loaded Q-factor. The amplitude characteristic of

the frequency-modulated signal generator, on which a wavemeter marker appears, is viewed simultaneously and used as a reference. By correcting the result to obtain the unloaded Q-factor of the centre conductor alone, the effective conductivity of the sample is obtained. Results of measurements on a number of samples of different conductors having various surface conditions, treatments and platings are given. These results are of value in the design of microwave components of all types where loss is a factor of importance. (Science Abstracts).

36. Bedard, F. and Meissner, H., "Measurements of Contact Resistance Between Normal and Superconducting Metals," Phys. Rev. 101, 26-30 (Jan. 1, 1956).

The contact resistance between crossed wires of Pb and Sn, Pb and Cu, Sn and Cu, Sn and In separated by their natural oxide layers has been measured at constant temperatures as a function of current direction and magnitude. Plots of these measurements in the case of a normal and a superconducting element show the resistance at low currents to be constant and to increase suddenly above a critical current. The low current resistance generally decreased with decreasing temperature. Calculation of the radius of the current-bearing area gives radii of atomic dimensions and shows that in some cases part of the barrier resistance disappears. Furthermore, four contacts showed an immeasurably small resistance at a temperature where only one of the contact members was superconducting. These measurements and earlier ones by others suggest a schematic representation of the resistance as a function of current and temperature. No significant rectification between normal conductors and superconductors was observed. (Science Abstracts).

37. Bendayan, J., "Apparatus for the Measurement of the 'dragging-out' (multiple-echo distortion) of a brief signal," Onde élect. 34, 153-62 (Feb., 1954). In French.

The paper describes two types of apparatus for the measurement of impedance irregularities in cables. In both cases a pulse input is used and the output from the cable is displayed on a c.r.t. The first type, suitable for the testing of long lengths of cable (e.g. several km), involves a direct display of the trailing edge of the pulse. The second type, intended for shorter lengths of cable, is based on an auto-correlation technique and involves the simultaneous generation of two pulse trains having different repetition rates, f_1 and f_2. At the receiving end a square-law detector is followed by a low-pass filter with a cut-off slightly below f_1 and f_2, the output being displayed on a c.r.t. swept at $|f_1 - f_2|$. Experimental tests with the two instruments on various cables are described, and illustrated with oscillograms. (Science Abstracts).

38. Benthem, C. W. and Kronig, R., "The Anomalous Skin Effect and Reflectivity of Metals," Physica 20, 293-300 (May, 1954).

It is shown that the standard theory of the skin effect and the reflectivity of metals is modified if the gas of conduction electrons is subject to internal friction. The energy dissipation resulting from this cause appears to furnish a contribution to the absorption factor of metallic conductors which can even become predominant at sufficiently low temperatures.

In this respect the mechanism in question acts in the same sense as the effects, studied by Dingle, which arise from the mean free path of the conduction electrons for collisions with the lattice becoming comparable with the skin depth. In practice the two effects should be superposed. The agreement between theory and experiment is thereby improved. (Science Abstracts).

39. Benz, F., "Impedance Measurement at High Frequency," Elektrotech. u. Maschinenbau 73, 434-40 (Sept. 15, 1956). In German.

A comprehensive review, with 27 references to fuller descriptions of different methods of h.f. impedance measurement, including resonance methods, bridge methods, measurement by means of tuned or untuned Lecher-wire systems, and methods utilizing waveguides. (Science Abstracts).

40. Bernard, J. J., The Thermal Resistance of Joints. Royal Aircraft Establishment (Gt. Brit.), AGARD rept. no. 212, (1958). AD-262 822 (June 61). 10pp.

The paper describes apparatus for studying the thermal contact resistance between conductors or between conductors and insulators and the extent to which this varies as a result of the tightening pressure. With regard to the thermal resistance of contact between thin sheets: there is a large difference in behaviour between joints made with massive plates and those made using rolled sheets; the thickest sheets, which have therefore been subject to less rolling, seem to have conductivities most sensitive to compression; for thick rolled sheets, the variation of resistance of the joint with pressure arises more from alteration of the conductivity of the material than from the contact resistance at the surface; the hysteresis effect previously reported is particularly noticeable in the case of rolled sheets. (ASTIA Technical Abstract Bulletin).

41. Blackband, W. T., "The Measured Effects at Super High Frequencies of Irregularities in Coaxial Cables," Proc. Instn. Elect. Engrs. 109B, 608-13 (May, 1961).

If the local characteristic impedance of a cable is not uniform along its length its characteristic impedance at high ratio frequencies will be frequency sensitive because of internal resonances. The results of the "uniformity of impedance" test of the British Services Specification DEF-14A carried out on about 50 cables are discussed. It is shown that there is a correlation between the measured impedance variations and in the first place the measured variations in cable core diameter and also with the amount of air trapped within the dielectric during the extrusion process. (Science Abstracts).

42. Blake, B. E., "'Dry Circuit' Contacts." In Electrical Contacts--1959, Papers Presented at the Engineering Seminar on Electrical Contacts, June 1959, at the Pennsylvania State University.

The author discussed laboratory testing of contacts to be used in dry circuit applications. The various voltage levels across the contacts which will cause irreversible changes in contact resistance are mentioned. The author states that contact tests should be primarily designed for the

purpose of determining the relationship between the environment and growth of surface films. Various environmental factors are discussed and the types of measurements which should be made on the contacts are listed.

43. Blake, Bruce E., "Some Measurements of Contact Resistance in an Accelerating Air Atmosphere," Oral Presentation at Penn. State Univ. Seminar on Elect. Contacts (June 17, 1958).

Results of a number of tests made on crossed-wire "dry contacts" using several different materials in an accelerating air atmosphere. Used special "jig" and 0.03" dia. wire contacts. Different pressures (30-600 grams) at a current of 10 ma were used. Resistances of 200Ω or higher were considered open circuits. Author concludes because of complexity of field environments, these results are useful only as guidance in contact design and direction of further studies. All measurements at D.C., no R.F. considerations given. Measurement made with a 4-terminal bridge.

44. Blitz, J., "Electrical Methods of Testing," Brit. Power Engng 3, 46-50 (Sept., 1961).

The particular cases described in outline include crack detection, thickness gauging, corrosion investigation, hardness testing, alloy composition and homogeneity, metal behaviour under strain. Resistivity/conductivity testing is frequently the basic electrical measurement and both direct resistance testing for crack detection and eddy current testing are fully discussed. Some commercial eddy current instruments mentioned are the C.N.S. tube tester, the "Conductiflex" and "Isometer" impedance and voltage measuring equipment. The "Magnatest Q" produces a curve which compares the properties of a ferromagnetic specimen with a standard. Finally the "Radiac" instrument is an eddy-current device suitable for both ferrous and non-ferrous materials and operates on the principle of modulation analysis. There is a short Bibliography. (Science Abstracts).

45. Bogdanovskii, C. A., "Investigation of Electric Contacts in the Electron Microscope," Fiz. Tverdogo Tela 1, 1281-1288 (Aug., 1959). In Russian.

Experimental studies of the behavior of electric contacts separated by only a few microns are difficult to make because it is not usually possible to observe the surfaces at high magnifications. In addition, the applied electric field distorts the surfaces making static experiments difficult. By mounting a pair of contacts in the specimen stage of an electron microscope the gap can be observed continuously at high electron-optical magnification while dynamical experiments are performed. Electron micrographs are shown illustrating the formation of sharp points on the cathode and long dendrites on the anode prior to complete breakdown and bridging over of the gap under an applied electric field which may attain a value of several million volts per centimeter. These pictures may be correlated with the measured volt-amp characteristics of the gap. (Science Abstracts).

46. Boháček, V., "A Simple Method for Measurement of H.F. Conductivity of Metal Coatings at Centimetre Wavelengths," Slaboproudý Obzor 19, 72-5 (1958). In Czech.

The method uses a section of cylindrical waveguide, in the centre of which is situated the measured cylindrical conductor. The latter is kept in

position by means of two dielectric spacers. The waveguide section operates as a semi-axial resonator; a TEM wave is excited in the space between the two cylinders; outside the intercylinder space the wave is rapidly attenuated. First, the Q-factor of the outer cylinder and that of the whole system are measured. These data are used to compute Q-factor of the measured conductor, Q_{im}. Quality factor of the inner cylinder, Q_i, is also calculated theoretically. The value of the h.f. conductivity, σ_{vf}, can then be determined from the relationship $Q_{im}/Q_i = \sqrt{\sigma_{vf}/\sigma}$, where σ is d.c. conductivity of the sample. (Science Abstracts).

47. Bolotovskii, B. M., "Skin Effect in Thin Films and Wires," Zh. éksper. teor. Fiz. 32, 559-65 (1957). In Russian. English translation in: Soviet Physics -- JETP (New York), Vol. 5, Nos. 3, 465-9 (Oct., 1957).

Equations are obtained for the skin effect in thin films and wires by using kinetic theory. A method is developed for the approximate solution of these equations which gives expressions for the impedance of thin films and wires. (Science Abstracts).

48. Bondarenko, V. V., Kvartskhava, I. F., Plyutto, A. A. and Chernov, A. A., "Resistance of Metals at High Current Densities," Zh. éksper. teor. Fiz. 28, 191-8 (1955). In Russian.

The results of an experimental investigation of the relation between the resistance of some metals, viz. copper, silver, platinum, etc., at current densities up to $10^7 A/cm^2$ are presented. The investigation was partly intended to find explanations for the phenomenon known as wire explosion, and also to determine the limitations of the validity of Ohm's law, if any. However, according to classic electron theory appreciable deviations from Ohm's law should occur only in the range $10^{10} - 10^{11} A/cm^2$ which cannot be reached experimentally yet. Modern refinements of the theory indicate that the limits of the accurate validity of Ohm's law must be some orders of magnitude lower than the above value, though such deviations are said to have been observed at densities of $\sim 10^6 A/cm^2$. These results did not stand up to carefully arranged tests, and the authors found Ohm's law satisfied at the highest current densities produced in their experiments. The currents were produced by an impulse circuit supplied by a capacitor discharge and oscillograms of the pulse form were taken. The energy relations obtained did not reveal any definite dependence of the resistance of the metal on the energy evolved and introduced into the wire. The experimental curves also enabled extrapolations to higher current ranges to be obtained by comparing the trends and relative extremes of the different metals investigated and therefore to conclude on a validity of Ohm's law up to at least $6.5 \times 10^7 A/cm^2$ for copper $6 \times 10^7 A/cm^2$ for silver, 1.5×10^7 for tungsten and 2.5×10^7 for platinum. At the highest current densities the temperature of the wires does not exceed a few hundred °C, but it is possible to obtain such current densities even at moderate temperatures. Even if a wire explosion is obtained (with W or Pt) at liquid-air temperature, the character of the energy-relation of R does not vary. (Science Abstracts).

49. Bonwitt, W. F., "Bolted Aluminun-Tp-Copper Connections," Trans. AIEE 67, 1208 (1948).

Connections with various platings and different compounds between contact

surfaces were subjected to 200 C. in a corrosive atmosphere of a 20 per cent NaCl solution atomized by pre-heated air. The criterion of performance was contact resistance. Properly made bolted connections are satisfactory although tinning or the use of a compound such as Penetrox A helps. (Science Abstracts).

50. Borovik, E. S., "Electric Conductivity of Metals at High Current Density," Dokl. Akad. Nauk SSR 91, 771-4 (1953). In Russian. English translation in: U. S. National Sci. Found. NSF-tr-140.

Bi, Pt, W and Cu have been studied at current densities ~10^6 amp/cm^2, using constant-current and pulse methods. The corrections to be applied for resistance changes due to heating and to the magnetic field of the current are discussed, and it is concluded that Pt, W and Cu show no deviations from Ohm's law, but that in Bi the increase in resistance from this cause reaches 30—40%. (Science Abstracts).

51. Boruff, Von H. and Miller, N. B., Evaluation of Ultrasonic Test Devices for Inspection of Adhesive Bonds. Martin Marietta Corp., Baltimore, Md., Quarterly progress rept. no. 11. AD-275 051 (Apr. 62).

The report presents an analysis and evaluation of the data received from the participants in the International Research Program sponsored by the Advisory Group for Aeronautical Research and Development (AGARD) of the North Atlantic Treaty Organization (NATO). This program is a cooperative endeavor by various members of NATO to evaluate nondestructive methods for inspection of bonded joints. (ASTIA Technical Abstract Bulletin).

52. Bourbonnais, T. L., II, "X-Rays Show Condition of Terminations," Elect. World 156, 46-7 (July 17, 1961).

The application of X-ray equipment to the examination of cable joints and terminations as a non-destructive inspection device, is briefly discussed. The advantages to be gained by its use are noted and the iridium isotope camera is mentioned as an alternative. Analysis of X-ray photographs of accessories have shown up constructional faults not located by initial high voltage acceptance tests, which at some later period could have resulted in electrical breakdown. (Science Abstracts).

53. Bourseau, J. and Sandjivy, H., "The Measurement of Coupling Impedance and Its Application to the Study of Cable Screens," Câbles et Transm. 10, 11-30 (Jan., 1956). In French.

A historical and critical review is given of the methods of measuring coupling (transfer) impedance. A new method is described in which the test sample is enclosed within a tubular screen which provides a return path for currents induced on the outside of the cable screen. Measured values of coupling impedance are quoted for various constructions of cable screens formed from helically applied tapes and steel wire braid. (Science Abstracts).

54. Bowcott, H. J. and Cleaver, A. J., "Corrosion of Electrical Components by Their Atmospheric Environment," Proc. Instn. Elect. Engrs., Paper 3624 [International Conference on Components and Materials used in Electronic Engineering], June, 1961, 8pp.

Mechanisms of atmospheric corrosion are first surveyed. Dry conditions are usually harmless except when hydrogen sulphide is present; above a certain critical humidity, electrochemical corrosion can occur, and is stimulated by gaseous and solid atmospheric contaminants such as sulphur dioxide and soot. Aggressive vapours may be evolved by organic insulating and packing materials. Corrosion may be enhanced at bimetallic contacts or where externally applied potential differences exist. Metallic "whisker" growth occasionally occurs. Next, possible effects of corrosion and whisker growth of electrical components are discussed. Failures may result from disconnections due to corrosion of wires, prevention of contact and clogging of moving parts by corrosion products, and from the making of unwanted contacts by metal whiskers, corrosion products and silver migration. A list of corrosion cases is then given, classified according to cause, illustrating some of the corrosion and fault mechanisms. The more interesting cases are commented on briefly. Finally, preventive measures are covered. The ideal environment is provided by a hermetically-sealed enclosure containing a dry uncontaminated inert gas. More practical steps include air purification, adequate ventilation of enclosed equipments, and avoidance of humid conditions and metal-surface contamination. (Science Abstracts).

55. Bowden, F. P. and Tabor, D., "The Friction and Lubrication of Solids," Oxford, Clarendon (1954).

56. Bowden, F. P. and Williamson, J. B. P., "The Influence of Electrical Current on the Contact Between Metals," Research Correspondence 7, S53-S55 (Oct., 1954).

Experiments are outlined which show that the contact between two blocks of gold is unchanged when the current passed is less than the critical size. A larger current causes the contact area to increase to a value determined only by the metal and maximum current. Transient values of the constriction resistance during the passage of current pulses were observed electronically. Simultaneous measurements of the mechanical strength of the contact imply that the current pulse has caused junction growth while there is evidance of localized melting in the contact region from microscopic examination of the surfaces. (Science Abstracts).

57. Bowden, F. P. and Williamson, J. B. P., "Electrical Conduction in Solids," Proc. Roy. Soc. 246, 1-12 (1958).

The effect of passing an electric current through the interface between two contacting pieces of gold has been investigated, and it has been shown that the current can cause appreciable changes in the true area of contact between the surfaces. The phenomenon has been studied by measuring the associated alterations in the constriction resistance. (This is the resistance caused by the constriction produced in the current stream as it passes through the tiny areas of contact between the metals.) It is shown that the response of the region of contact may be explained as a result of the heat generated in this resistance by the current. For any given current there is a certain critical degree of constriction through which it will just pass without causing a permanent change in the contact region; if the current flows through a contact area which presents a constriction resistance greater than this critical value, then the heat

generated will be sufficient to cause the yield pressure of the metal near the interface to fall, and the area of contact will increase accordingly. The critical constriction resistance associated with any current has been found to be inversely proportional to the magnitude of the current. The response of the contact region to short-duration pulses of current has been studied. The results show that the behavior is independent of the length of the pulse in the range investigated (10 μsec to 10 msec). They also indicate that when a short pulse of current passes between the pieces of metal mechanical collapse will occur only if the current is sufficiently large to cause melting of the metal near the interface. It is possible to calculate the temperature in the contact region from the potential difference developed across the constriction. Calculations based on the accepted mathematical treatment indicate that mechanical collapse occurred in these experiments when the temperature at the interface was raised to about 950 C. (This is significantly below the melting point of gold, 1063 C.) This result was not supported by direct examination of the specimens, which showed clear evidence of melting whenever collapse occurred. It is suggested that the accepted mathematical treatment of constriction resistances may not be valid when the temperature approaches the melting point. (Science Abstracts).

58. Boyer, O. A. and Korges, E., "Connector Performance by Types," Trans Amer. Inst. Elect. Engrs. III 75, 907-13 (1956).

Gives test results from 149 overhead-line connectors of the compression, split-bolt, parallel-groove, U-bolt and hot-line types, the tests comprising outdoor exposure over 38 months to a cycle of 100 A at 12 min on and 12 min off. Resistance was measured each week and failure considered to occur when the clamp became electrically unstable or failed mechanically. All were satisfactory except the hot-line clamps but the compression-type is the simplest and most convenient. (Science Abstracts).

59. Brand, H. and Schuon, E., "Instrument for Measuring Very Small Inductances," Elektron. Rdsch. 11, 65-7 (March, 1957). In German.

The range of inductances measured covers 0.001 to 0.5 μH. The inductance to be measured is connected, through a quarter-wave transformer, to the input of a distributed line of variable length, which is short-circuited at the other end. As the length is varied, resonance occurs and from the known length the value of the inductance can be determined. The source of RF and the resonance indicator are coupled to the measuring system by small dipoles. The instrument described uses 375 Mc/s, and the wave impedances of the two lines in the system are 166.5 and 215.2 ohms; the geometric mean value of the range is then 0.05 μH. Formulae used are derived and the effect of stray capacities is discussed. The self-capacity of the measured inductance changes the result of measurement. Practical construction of the instrument are compared with the theoretically calculated values, and good agreement is shown. (Science Abstracts).

60. Briscoe, E. M., "Fundamentals of Electrical Contacts," Elect. Times 132, 845-8 (Nov. 28, 1957).

Considers the mechanism of electric performance of a contact pair, operating under varying degrees of contact pressures and effective areas. The

elementary contact, contact resistance, the practical contact, nominal area and control efficiency are discussed. (Science Abstracts).

61. Brown, T. W., Ultrasonic and Eddy Current Non-Destructive Investigation of Hollow Aluminum Extrusions. Northrop Corp., Hawthorne, Calif., Rept. no. NOR-60-138. AD-270 412 (18 May 60). 28pp.

Ultrasonic inspection techniques on Al alloy extrusions joined by pressure welding have shown the best correlation of defect detection and location. Improved equipment can present a pattern on an oscilloscope that will give the approximate size and the plane in which the defect lies. Qualitative correlation existed between ultrasonic indications and eddy current indications, however, little or no quantitative correlation existed. Improved inspection techniques could increase the efficiency of the eddy current system. The design requirement of detecting defects as small as 10% of the finished wall thickness was met only when the defects were located away from the wall surfaces and were in the correct plane for proper reflection of the return sound beam. Work on the acceptance criteria was not completed. This was based upon the decision to fabricate the canopy extrusion, with a different die design which did not require pressure welding. (ASTIA Technical Abstract Bulletin).

62. Brunot, A. W. and Buckland, F. F., "Thermal Contact Resistance of Laminated and Machined Joints," Trans., Am. Soc. Mech. Engrs. 71, 253-256 (April, 1949).

Values are reported for two types of joints: between two blocks of laminated steel, either in direct contact or separated by cement or shims of steel, aluminum, or aluminum foil; and between two blocks of cold-rolled steel with various surface finishes. The resistance measured amounts to 0.3 to 8 in. of additional material, depending upon configuration. Results are also given in terms of contact resistance. (Battelle Library Review).

63. Buchan, R. J., "Connector Design Considerations," Electronic Indust. 20, 91-5 (July, 1961).

Surveys the requirements for low power contacts. Gold/silver plated contacts are recommended for low voltage operation since they have one-tenth the resistance of nickel/silver contacts. (Science Abstracts).

64. Bulla, W., "The Importance of Earthing As a Protective Measure," Elektrizitätswirtschaft 60, 628-34 (Sept. 5, 1961). In German.

Practically all aspects of earthing are dealt with. From the earth's crust and the nature of the different surfaces facilitating good-to-poor earth contact, the author goes on to high voltage systems. Fault clearance times of switchgear, the earthing of pylons and their lightning conductors, with a note on double earth faults and the unsuitability of the usual pylon earthing methods in preventing dangerous "contact voltage" in such circumstances are discussed. Medium voltage distribution systems and plant installations are considered, as well as neutral point earthing and the bonding of cable armouring, metal casing thereto and to water mains. The advantages to be obtained by bonding and earthing all other service pipes to water pipes to obtain a lower resistance to earth are explained and, it is claimed, bonding gas pipes to the electrical earthing system

reduces fire risk. The favourable attitude of Swiss water supply authorities is compared with that of similar German undertakings to the use of water mains for electrical earthing purposes and difficulties caused (to electrical concerns) by non-metallic sections are mentioned. A review of distribution systems in villages and housing estates is included and, finally, it is stated that portable apparatus is responsible for about 70% of the fatal accidents on low voltage systems. A lively discussion took place. (Science Abstracts).

65. Burley, C. E., "Silver-Plated Aluminum Bus Conductor," Trans. Amer. Inst. Elect. Engrs. III 77, 1024-8 (1958).

The use of aluminum for bus-bar conductors is restricted by difficulties of ensuring good contact surfaces; this may be overcome by silver-plating the conductor. A successful process has been developed in which successive layers of zinc, copper and silver are deposited over the entire conductor, producing a coating which is very adherent, free of porosity, and has good abrasion resistance and maximum "formability" consistent with other requirements. Tests are described which include investigations of blistering; joint resistance before and after accelerated fog-spray corrosion tests; temperature rise of joints in cyclic current loading; bend tests to check formability of plating; and corrosion resistance tests of flat and bent areas. (Science Abstracts).

66. Bussey, H. E., "Standards and Measurements of Microwave Surface Impedance, Skin Depth, Conductivity and Q," IRE Trans. Instrumentation I-9, 171-5 (Sept., 1960).

The walls of a cavity resonator become standards of skin depth, and of effective conductivity, when the internal Q is determined, if the walls are either uniform or intercompared, and if contact losses are eliminated. A four year old copper standard has 95% of its theoretical Q, (accuracy of this result is estimated as $\pm$2%), and deoxidation raises the value to 98%. The Q measuring system, accurate to 1%, is described. Equations are given for the complex frequency pulling of a resonator by the wall impedance. (Science Abstracts).

67. Butler, F., "A.C. Bridges with Inductive Ratio Arms," Electronic Technol. 37, 303-309 (Aug., 1960).

Compensation for leakage reactance by using a procedure involving two balance conditions, is shown to greatly reduce errors occurring with transformers of normal design.

68. Chaikin, Saul W., Study of Effects and Control of Surface Contaminants on Electrical Materials. Stanford Research Inst., Menlo Park, Calif., Semi-annual technical rept. no. 1. AD-246 647 (15 Sep. 60). 68pp.

Exposure of clean palladium and gold contacts to organic vapors results in spontaneous formation of an organic film on the metals. Palladium is much more reactive than gold, but gold is not inert. The organic deposit was detected by a Probe Instrument and by electron observations. Electron microscope observations were performed by using a specially developed

replica technique which does not interfere with the organic deposit on the contacts. The texture and consistency of the organic deposit determined whether agreement was obtained between the Probe Instrument results and the electron microscope results. Often the electron microscope would show a deposit but the contact would be clean according to the probe; this suggests a liquid deposit. Palladium exposed to ethylbenzene at room temperature exhibited a contact resistance increase in about 2 weeks. Vapors of the hydrocarbon, limonene, caused deposits to form on palladium in less than a week at room temperature (by electron microscope observation). The deposits steadily increased in thickness and extent through a period of about two months. Probe measurements indicated considerable contamination after about two weeks; the values after that were erratic, depending on the consistency of the deposit. Gold developed deposits (electron microscope) at the 36-day mark, but only exhibited increased contact resistance after about 2.5 months. In preliminary experiments, frictional polymer formation was demonstrated in less than five minutes when palladium was rubbed against palladium in an atmosphere of limonene. (ASTIA Technical Abstract Bulletin)

69. Chaikin, Saul W., Study of Effects and Control of Surface Contaminants on Electrical Materials. Stanford Research Inst., Menlo Park, Calif., Final rept. AD-261 743 (10 June 61). 79pp.

The cause of objectionable contact resistance was studied in relay contacts used in milli-voltmicroampere switching. Organic deposits form spontaneously on noble metal contact surfaces. Deposits formed over a period of weeks or months from a number of pure organic compunds and, as well, from rosin flux and from Teflon and Kel-F. Insulating deposits were detected with a fine wire probe and with the electron microscope. Frictional polymer, formed when metals are rubbed together in an organic environment developed from outgassing rosin flux and Teflon and Kel-F. Four metals were found to generate decreasing amounts of frictional polymer in the order: Pd, Au-alloy, Au, Ag, with the following approximate activity ratios: 100, 10, 2, 0.1. A non-destructive relay test for contact contamination was developed based on monitoring at dry circuit load levels and a contact resistance sensitivity of 0.1 ohm. The relays were put through a 7-step schedule in which time, temperature, and relay cycling were varied. (ASTIA Technical Abstract Bulletin).

70. Chaikin, S. W., Anderson, J. R. and Santos, G. J., Jr., "Improved Probe Apparatus for Measuring Contact Resistance," Rev. Scientific Instruments 32, 1294 (Dec., 1961).

An apparatus, employing a fine-wire probe, for the detection of insulating surface films on metal surfaces is described. A chemical cleaning procedure to prepare reliably clean palladium and gold surfaces is reported, and examples of the reproducibility of the method are given. Examples of the use of this apparatus include: the detection of high resistance areas on relay contacts taken from sealed relays, and a study of insulating base metal oxide impurities in commercial relay contacts. In the latter work, a sensitized paper test showed areas of iron and copper deposits on the contacts which could be correlated with areas of high resistance as indicated by the probe. (Science Abstracts).

71. Chambers, R. G., "The Effect of Relaxation on Microwave Measurement of the Anomalous Skin Effect," Physica 19, 365-70 (April, 1953).

In using anomalous skin effect measurements at microwave frequencies to estimate the parameter σ/l, it has generally been assumed that relaxation effects could be neglected. Dingle's new calculations make it possible to check this assumption, and to give methods of detecting the effects if they are appreciable. It is found that for normal metals the effects are small at frequencies up to 20000 Mc/s, but that for bismuth they are large enough to reduce the estimate of σ/l from its previous value, 2.74×10^7 ohm^{-1} cm^{-2}, to 1.53×10^7 ohm^{-1} cm^{-2}. (Science Abstracts).

72. Chambers, R. G. and Park, J. G., "Measurement of Electrical Resistivity by a Mutual Inductance Method," Brit. J. Appl. Phys. 12, 507-10 (Sept., 1961).

The resistivity of a sample can be deduced from the change in mutual inductance between two coils when the sample is inserted. It is shown that with simple equipment for measuring mutual inductance over a range of frequencies, the method can be used to measure resistivities from 2×10^{-9} ohm cm upwards, and the necessary functions are tabulated. (Science Abstracts).

73. Chaston, J. C., "Some Effects of Surface Films on Contact Behavior," Proc. Inst. Elect. Engrs. 100, 155 (1954).

Dealing with the production and effect of tarnish films formed by chemical reactions between base metals. The contamination may consist of surface films of oxides or sulphides as well as of grease, oil and particles of dust, and he discussed in particular the characteristics of the films formed in industrial atmospheres, giving special attention to the properties of sulphide films on silver. He discussed the acceleration of tarnishing due to heating, and pointed out that there are many film, such as those of silver sulphide and platinum oxide, which decomposes at a higher temperature. He stressed the case in which arcing would cause tarnishing which would increase the resistance, and then subsequent heating due to current carried would tend to remove the surface film. He mentioned in particular the operation of contacts in an enclosed container in which trouble is caused through volatile material such as cellulose varnishes and finishes. (ASTM Bibliography and Abstracts on Electrical Contacts).

74. Chatfield, C. H., "Silver and Silver Alloys; Properties and Design Applications," Elec. Mfg. 64, (October, 1959).

A review of the physical and electrical properties of silver and silver alloys in the design of electrical and electronic equipment. Electrical conductivity, corrosion resistance, fabricability, and reliability are explained and supported by charts, tables, and applications. (ASTM Bibliography and Abstracts on Electrical Contacts).

75. Chatterjee, S. K., Shenoy, P. R. and Bai, C. R., "A Method for the Measurement of Conductivity of Metals at Microwave Frequencies," J. Indian Inst. Sci. B. 36, 107-22 (July 1, 1954).

A theory has been worked out with the aid of field equations. An expression for the reflection coefficient in terms of voltage standing-wave ratio, attenuation constant, scattering coefficient of any waveguide discontinuity present in the system and phase factors has been derived. The values of conductivity for several metals obtained by this method agree well with

values obtained by other existing methods. (Science Abstracts).

76. Cherry, Lloyd B., "Dynamic Resistance Test of Spot Welds," IEEE Trans. on Communications and Electronics (May, 1963).

Method of obtaining quality of spot welded joints by applying a periodic pressure to the joint in the presence of a test current, and measuring the potential across the weld. Method may use D.C. test current or A.C. and phase locked pressure variation. Potential across weld is amplified, magnitude (in case of D.C. test current) is function of poorness of weld. In case of A.C. test current, higher harmonic content is indicative of poorness of weld. Greatest advantage allows detection of poor welds not detectable on visual inspection. May be useful in checking soldered connections for low frequency electrical characteristics and mechanical strength.

77. Chester, M., "Evidence for a Configurational E.M.F. in a Conducting Medium," Phys. Rev. Letters 5, 91-3 (Aug. 1, 1960).

By analogy with the hydrodynamics of flow of a liquid through a constriction it is argued that the flow of conduction electrons through a solid should speed up at a constriction, and energy conservation demands an extra e.m.f. to be developed in the system. Experiments on thin Bi films indicate that this e.m.f. exists but numerical agreement with a simple theory is poor. (Science Abstracts).

78. Chiotti, P., "Measurement of the Electrical Resistance of Metals and Alloys at High Temperatures," Rev. Sci. Instrum. 25, 876-83 (Sept., 1954).

An a.c. potentiometric method is described. The potential developed between two probes which make contact with the test-piece is balanced against a potential developed across the secondary of a current transformer. The primary of the current transformer is connected in series with the test-piece. The test-piece in the form of a bar is mounted between water-cooled copper electrodes and is heated by passing a heavy 60 c/s current through it. The resistance is measured directly. A furnace and automatic recording and control instruments which can be used in conjunction with this method are described. (Science Abstracts).

79. Clarke, W. W. H. and Hinchliffe, J. D. S., "The Evaluation of Cable Irregularities at Very High Frequencies," Proc. Instn. Elect. Engrs. 101, 55-60 (Feb., 1954).

The magnitude and distribution of cable irregularities are related statistically to the end-to-end input-impedance difference under conditions involving a large number of wavelengths and appreciable attenuation. The manner of variation of the measured quantities with frequency and irregularity magnitude and distribution is revealed. These relationships are shown in the form of master curves for a particular cable on the assumption of exponential fault correlation. (Science Abstracts).

80. Cocks, M., "The Effect of Compressive and Shearing Forces on the Surface Films Present in Metallic Contacts," Proc. Phys. Soc. 67, 238-248 (1954).

Two electrical methods have been used to examine the extent to which the oxide or other natural surface films can prevent intermetallic contact

when metal bodies are pressed together. One consisted of measuring the electrical resistance of the contact, the other of measuring the thermoelectric force which arises when there is a temperature gradient across the film; crossed cylinders were used for the contact members. Precautions were taken to minimize vibration and shearing forces when applying normal loads. The contact resistance was often as large as several ohms, showing that penetration of the films was negligible, and in some cases the variation of resistance and thermoelectric force with load was consistent with the assumption that the contact contained a uniform film. Friction forces up to a certain critical value could generally be exerted in the normally loaded contacts before any metallic contact appeared, and in certain cases the films remained intact even during the sliding. When the film was penetrated, the area of metallic contact was small at first, but grew as sliding proceeded; there was a simultaneous growth in the force resisting sliding. Microscopic examination showed that the metal surfaces suffered severe damage only after an appreciable distance of sliding (of the order of 0.1 mm). (Science Abstracts).

81. Cocks, M., "Surface Oxide Films in Intermetallic Contacts," Nature 170, 203-4 (Aug. 2, 1952).

With the exception of gold and silver, it is shown that, in general, metals are covered with a thin oxide layer which increases markedly the resistance of metals in contact. These layers are not penetrated on normal loading, a lateral force being required, whereupon the contact resistance decreases and the frictional force increases. (Science Abstracts).

82. Codelupi, R., "Impedance Measurement on Coaxial Cables by Means of the Pulse Echo Tester," Note Recensioni Notiz. 9, 1006-1033 (Nov./Dec., 1960).

83. Cole, R. S. and Honeyman, W. N., "Two Automatic Impedance Plotters," Electronic Engng. 30, 442-6 (July, 1958).

Describes two methods by which impedances at microwaves frequencies can be automatically presented. The theory of the two systems is indicated and practical details of each are given with a comparison of the two. (Science Abstracts).

84. Committee Report, "Bibliography of Relay Literature 1953-1954," Trans. Amer. Inst. Elect. Engrs. III 76, 126-9 (1957).

85. Committee Report, "Bibliography of Relay Literature 1955-1956," Trans. Amer. Inst. Elect. Engrs. III 78, 78-81 (1959).

86. Committee Report, "Bibliography of Relay Literature 1957-1958," Trans. Amer. Inst. Elect. Engrs. III 79, 39-42 (1960).

87. Committee Report, "Bibliography of Relay Literature 1959-1960," Trans. Amer. Inst. Elect. Engrs. III 81, 109-12 (1962).

88. Committee Report, "Bibliography on Ground Resistance and Potential Gradient Measurement," Trans. Amer. Inst. Elect. Engrs. III 79, 52-8 (1960).

89. Compton, K. G. and Baker, R. G., "The Use of Electroplated Metals in Static Contacts," Engr. Seminar on Elect. Contacts, Penn. State Univ. (June, 1960).

Results of two studies of contact resistance. First deals with crossed cylinders (wires) at pressures from 0-1500 grams using several electroplated materials. Presents data before and after exposure to atmosphere at 3 different locations, for contacts "wiped" and not wiped. Results indicate noble metal plating of sufficient thickness, a soft metal (solder) has most reliability. In all cases, "slid" or "wiped" contacts offered lower contact resistance. Second study dealt with actual connectors and printed circuit boards with selected metallic finishes. Contact resistance measurements were taken periodically. Only connector and board assemblies that successfully finished test (28 mo.) were ones with 50/50 tin-lead solder on contact surface. Additional studies being made on wear resistance. No considerations made concerning RF impedance, all measurements at D.C. Includes a lot of data on many types of metals.

90. Comte, G., Bouderlique and Thevenet, G., "Echometer with Very Short Duration Pulses for the Study of Coaxial Pairs for Television," Câbles et Transm. 7, 263-9 (July, 1953). In French.

An echometer has been constructed using a 0.02 μsec pulse. The pulse-forming circuits and distributed amplifiers used are described. With short pulses, it is possible to locate faults in short lengths of cable (<40 ft). A set of echo records for the same length of cable taken with pulse widths of 0.1, 0.05, 0.04 and 0.02 μsec shows the improvements in resolution obtainable with progressive reduction in pulse width. (Science Abstracts).

91. Conard, Barton L., A Report on the Design and Construction of a Shielded Mobile Laboratory. ACE Engineering and Machine Co. Inc., Huntingdon Valley, Pa., AD-326 550 (2 Aug. 61). 36pp.

92. Conner, T. J. and Wilson, W. R., "Performance of Electrical Joints Utilising New Silver Coating on Aluminium Conductors," Pwr Apparatus Syst. 7, 702-12 (Aug., 1953).

A new process of Ag-plating of aluminium is described for elimination of joint failures which might be due to high-resistance Al_2O_3 film. The advantage of Ag is that its contact resistance, if raised by filming, characteristically decreases in value during normal operation, and a curve is included showing self-cleansing properties of sulphided Ag contacts at load currents. Whereas many joints are between Cu and Al, addition of Ag plate does not introduce a new corrosion problem but shifts corrosion away. Data are given for 144 joint treatments. Tables of endurance tests under high-humidity and also under salt-spray conditions, indicate highly stable performance. The bond between the Ag and Al is stronger than either metal. On high current tests, the Ag-Al joints remain undamaged, and on a 6-month cycle run no Ag-plated Al joint increased its contact resistance. A lengthy discussion is reported. The investigation does not include Al cables and connectors. (Science Abstracts).

93. Cotte, M., "Study of a Factory Length of Cable by Measurements of Terminal Impedance," Câbles et Transm. 9, 161-71 (April, 1955). In French.

A length of cable is terminated in its characteristic impedance and its terminal impedance is measured from the open end at a series of frequencies for which $\beta l = n\pi$. The real and imaginary components of the terminal impedance are a measure of the coefficients of a Fourier series which defines the variation of local impedance along the cable. A method of correction for cable attenuation is given. It is proved that the variations in local impedance must be real. The results of such measurements agree well with those derived by other methods. (Science Abstracts).

94. Courtney-Pratt, J. S. and Eisner, E., "Contact of Metallic Bodies: Effect of Tangential Force," Engineering 185, 182-183 (Feb. 7, 1958).

A study of the relative tangential movements of two bodies and the size of the area of contact between them, when they are first loaded normally against each other and then subjected to tangential forces too small to cause sliding. (Battelle Technical Review).

95. Crawford, G. J. B. and Dixon, G. H., "Bridge for the Measurement of Small Condensers Paralleled by Small Resistors," Rev. Sci. Instrum. 27, 972-3 (Nov., 1956).

A simple equal ratio-arm bridge in which the sample is measured by substitution. One supply point is earthed; the detector is a differential amplifier of high input impedance. The upper frequency-limit is about 10 Mc/s. (Science Abstracts).

96. Cutler, M., "Thermoelectric Measurements at Small-Area Contacts," J. Appl. Phys. 32, 1075-82 (June, 1961).

Measurement of the effects of heating a substance in the vicinity of a metal contact by means of an electrical current leads to the determination of various combinations of the thermoelectric parameters sufficient to determine the electrical conductivity, the thermal conductivity, and the Seebeck coefficient. If the metal contact is small, radiation causes negligible error in the determination of the thermal conductivity. One of the combinations obtained directly is the thermoelectric figure of merit. Equations are derived which relate to the heating current an observed thermoelectric voltage or change in resistance caused by a change in temperature at a small area contact. Geometric factors are found to cancel out of these equations. Quantitative relations are also presented which set limits on the effects of radiation. An experimental method is described which was used for making such measurements, and some experimental results are reported which permit comparison to conventional measurements in accuracy. Ways in which measurements of thermal diffusivity can be combined with the other measurements are also discussed. (Science Abstracts).

97. Dassetto, G., "Aluminium Bus Bars," Bull. Assoc. Suisse Elect. 51, 2-14 (Jan. 16, 1960). In French.

Summarizes the characteristics of aluminium and copper as materials for the construction of busbars and discusses the factors which determine the cross-sectional area required to carry a given current. A formula is developed which takes all these factors into account and a table is reproduced showing the electrical and physical properties of aluminium conductors of varying sizes. Emphasis is given to the effect of different aluminium sections on heat dissipation and resistance to physical loads imposed under short-circuit conditions, with particular reference to the advantages of a double "T" over the double "L" or double "U" sections more commonly used. Concludes with advice on the most suitable methods of making aluminium-copper and aluminium-aluminium joints. (Science Abstracts).

98. Davidson, P.M., "The Theory of the Thomson Effect in Electrical Contacts," Proc. A.I.E.E. 96, 293-295 (Nov., 1949).

A general theorem is given concerning the influence of the Thomson effect on the location of the maximum temperature in an electrical contact. Its application to the theory of fine transfer in electrical contacts is discussed. (Science Abstracts).

99. Davies, W., "Thermal Transients in Graphite-Copper Contacts," Brit. J. Appl. Phys. 10, 516-522 (Dec., 1959). [See also Brit. J. Appl. Phys. 11, 389-390 (Aug., 1960)].

Calculation of the transient temperature distribution in a current-carrying electric contact is important in those cases in which the contact members make actual contact for only a comparatively short time. Special reference is made here to the contact of graphite and copper, and consideration is given firstly to the case in which the metal is clean, and secondly to that in which the metal is covered with a film of oxide. Finally, the decay of the temperature at a contact spot following the separation of the contact member is discussed. The analysis treats of a single circular contact spot of very small radius. (Science Abstracts).

100. Dekabrun, L. L., "Regenerative Measuring Pickups," Avtomatika i Telemekhanika 17, 1114-1122 (Dec., 1956).

101. de la Groce, P., "Influence of the State of Surface the Conductivity of Electrical Contacts," Journées des États de Surface, TA407 P21j, 223-226 (1946). In French.

Theoretically analyzes the above problem. Data for Ni, Cu, and Al are charted and interpreted for different surface conditions. (Battelle Library Review).

102. Deschamps, G. A., "Impedance Measurements and Standards," J. Res. Nat. Bur. Stand. 64D, 598 (Nov.- Dec., 1960).

A short survey of publications in this field for the 3-year period up to the 1st January 1960. Most of the 21 papers referred to concern measurements at microwave frequencies. (Science Abstracts).

103. Deschamps, G. A., "Additional Comments on Impedance Measurements and Standards," J. Res. Nat. Bur. Stand. 65D, (Jan.-Feb., 1961).

104. Diebold, E. J., "Temperature Rise of Solid Junctions Under Pulse Load," Trans. Amer. Inst. Elect. Engrs. I 76, 593-8 (1957).

Junctions subjected to pulse currents have a temperature rise that depends on dimensions, materials, and cooling, as much as magnitude, duration, and form of the pulse. Short pulses heat only a part of the body containing the junction; longer pulses permit the heat to penetrate deeper. Short pulses of constant magnitude, or linearly increasing in time, or capacitor discharges, show only a small difference in temperature rise. Experiments conducted with capacitor discharges are easily interpreted for other pulse shapes. For larger pulses, successive approximations are useful; plane heat flow in the junction material, plane flow in the junction and in the main body, spherical diffusion in the body, and simultaneous heating of the body with external cooling. Each approximation has its range of validity, expressed as pulse durations. Approximations overlap between ranges and cover the full span from infinitely short pulses to continuous load. A complete example is discussed. (Science Abstracts).

105. Dietrich, I., "Experiments on the Superconductivity of Contacts," Z. Phys. 133, 499-503 (1952). In German.

Contacts between Ta electrodes covered with TiO_2 or CeO_2 layers 15 to 40 Å thick become superconductive. The dependence of the transition curves on thickness and current is investigated. (Science Abstracts).

106. Dietrich, I. and Ruchardt, E., "Thermal Potentials in Platinum Contacts," Z. Naturforsch. 4a, 482-486 (Oct., 1949). In German.

It is shown experimentally that the thermal potential observed when crossed Pt wires are unsymmetrically heated is due to a thin film of impurity between them. The thermal potential and the thermal resistance of the unimolecular impurity film were determined. The measurements were in good agreement with values calculated from the theory of Kohler. (Science Abstracts).

107. Dietrich, I., "Thermoelectric Currents on Contact With Monomolecular Films of Impurities in Monometallic Circuits," Z. Angew. Phys. 1, 377-382 (May, 1948). In German.

This proves experimentally that the thermoelectric voltage, which appears when two crossed gold rods are heated on one side only, is caused by a thin film of foreign matter at the points of contact. The magnitude of the voltage agrees with Kohler's work, and the film resistance follows the Wiedemann-Franz law. Includes diagrams and graphs. 14 references. (Battelle Library Review).

108. Dietrich, I., "Peltier Effect in Monometallic Contacts," Z. Angew. Phys. 2, 128-31 (1950).

It was found that an effect analogous to the Peltier effect is observable in a monometallic contact, provided an impurity film is present. The

effect disappears at high temperatures. Theory and experimental data are given. (Science Abstracts).

109. Dietrich, I. and Honrath-Barkhausen, M., "Experiments on the Transport of Matter in Make and Break Contacts Using Radioactive Isotopes," Z. angew. Phys. 12, 538-44 (Dec., 1960). In German.

Transport measurements were made using contacts made from various metals. The contributions of the bridge and the arc to the transport is discussed. The authors consider that their results are in agreement with previous work on the nature of the liquid bridge. (Science Abstracts).

110. Dietrich, I. and Honrath-Barkhausen, M., "On the Formation of Resistive Layers of Organic Origin on Electric Contacts," Z. angew. Phys. 11, 399-403 (Oct., 1959). In German.

A tracer technique using C^{14} was used to study the formation of thin layers on electrical contacts resulting from the decomposition of organic substances. Two types of a layer formation occur; one takes place when current passes through the contacts and the other takes place in the absence of current. Adsorption measurements were made to clarify the latter mechanism but so far these are inconclusive. (Science Abstracts).

111. Dilworth, C. C. (Miss), "The Influence of Surface Films on the Electrical Behavior of Contacts," Proc. Phys. Soc. 60, 315-25 (April, 1948).

The variation of current with voltage at an idealized contact between two crystals of a semiconductor is calculated on the assumption that electrons penetrate the surface barrier by tunnel effect. Comparison with experimental curves for silicon carbide powders leads to the conclusion that these crystals are covered by an insulating surface film, which affects the rectifying properties of the crystal when it is in contact with a metal. It is shown that this can account for the discrepancies observed between experimental curves and those deduced from the simple Schottky theory of rectification. (Science Abstracts).

112. Dingle, R. B., "The Anomalous Skin Effect and the Reflectivity of Metals," Physica 19, 311-47 (April, 1953).

It is shown that considerable simplifications may be effected in some of Reuter and Sondheimer's formal expressions for the electric field in a metal when the skin effect is anomalous. The formal solutions for the surface impedance are evaluated without recourse to direct numerical integration. Special attention is paid to the optical regions, where the results assuming diffuse reflection of electrons at the metallic surface are found to be quite different from those assuming specular electron reflection: in particular, the optical absorptivity of metals assuming diffuse electron reflection is especially for good conductors at low temperatures, much greater than that calculated on the assumption of specular electron reflection, or that calculated by usual standard theory ignoring the anomalous nature of the skin effect. Tables are constructed of the surface resistance and reactance in the microwave region for both specular and diffuse electron reflection, and in the infrared for diffuse electron reflection. Explicit formulae are derived for the optical properties of metals in the near infrared, visible and ultraviolet, both for

specular and for diffuse surface reflection of electrons. (Science Abstracts).

113. Dingle, R. B., "The Anomalous Skin Effect and the Reflectivity of Metals. II. Comparison Between Theoretical and Experimental Optical Properties," Physica 19, 348-64 (April, 1953).

It is shown that the observed optical properties of metals are in much better agreement with theoretical values taking into account the anomalous nature of the skin effect and assuming diffuse reflection of electrons at the metallic surface than with those assuming specular electron reflection, and in discord with the predictions of standard theory ignoring the anomalous nature of the skin effect. The metals discussed are Na, Cu, Ag, Au, Pt, W, Al, Pb and Sn, principal attention being paid to the infrared, so as to avoid complications due to the photoelectric absorption bands normally present in the visible and ultraviolet. Suggestions are made for future experimental work. (Science Abstracts).

114. Dixon, C. R. and Nelson, F. G., "The Effect of Elevated Temperature on Flash-Welded Aluminum-Copper Joints," Trans. Am. Inst. Elect. Engrs. II 78, 491-5 (1959).

A report of an investigation of 500 joints in 1/4 in. by 1-1/2 in. bar, made by an improved technique using a 250 kva machine. The welding procedure is described and results of tensile tests, impact tests and electrical resistance measurements are tabulated. Photomicrographs are also included. The conclusions are: (1) the average strengths of the welds were at least 10,000 lb./in^2 when heated as high as 300°F for 2 years, 370°F for 1 year, 450°F for 144 hours, 500°F for 36 hours, 600°F for 2 hours, or 700°F for 5 minutes, (2) the strengths of individual welds may drop below 10,000 lb./in.^{2} when joints are heated for 48 hours or more at 500 F, or when heated for shorter times above that temperature, (3) there was no evidence of embrittlement at any of the heating conditions used. (Science Abstracts).

115. Dormont, H., "On Contact Phenomena," C. R. Acad. Sci. 236, 1238-1240 (March 23, 1953). In French.

It is shown that when the work function and barrier transparency depend slightly on temperature (ϕ, A of the form ϕ_0, A_0 (1 + aT)) the c.p.d. is given by $v' - v + kT (\log c/c' - \log D_0/D_0')$ where the v's are the work functions measured at absolute zero, the D_0's are the barrier transparencies and the c's are $A_0 e^{-alk}$ for the two materials. (Science Abstracts).

116. Dremel, W., "Contact Resistance of Silver-Cadmium and of Silver-Cadmium Oxide, and Its Dependence on the Contact Radius," Dtsch. Elektrotech. 12, 329-33 (Sept., 1958). In German.

The resistance of such contacts was measured and was found to agree with theory, assuming that as the contact pressure increases the deformation is at first elastic and later plastic, and that the contact surfaces are covered with a thin film of foreign material which breaks at high pressure. (Science Abstracts).

117. Druey, W., "High-Frequency Measurement Technique," Bull. Ass. Suisse Elect. 42, 989-99 (Dec. 15, 1951). In German.

A number of separate aspects are treated; the use of pulse-multiplex h.f. radio links for telemetry, the present state of international standardization, the measurement of current, voltage and frequency. Examples are shown of equipments for the accurate determination of dielectric constant and loss, and for the measurement of time (quartz clock). In the very highest frequency regions the application of distributed amplification and of the traveling-wave oscillograph is described. (Science Abstracts).

118. Druey, W., "High-Frequency Measurement Technique," Bull. schweiz. elektrotech. Ver. 42, 989-1000 (Dec., 15, 1951). In German.

A survey paper dealing with measurements of current, voltage, impedance, dielectric properties, frequency and time. A description is given of a telemetry system using a h.f. channel, and the advantages of distributed amplifiers for wide-band operation in c.r. oscillography are discussed. (Science Abstracts).

119. Druey, W., "High-Frequency Measurement Technique," Tech. Mitt. schweiz. Telegr.-Teleph. Verw. 30, 50-56 (July, 1954). In German.

120. Dubas, E. R., Dry Circuit Tests and Test Equipment for Acceptance Testing of Relays for Low Level Application. Union Switch and Signal Div., Westinghouse Air Brake Co., Pittsburgh, Pa., Final engineering rept. AD-257 498 (1 May 61). 61pp.

Investigations were made to develop a set of airborne electronic relay acceptance tests which would allow accurate prediction of reliable operating relay life. It was concluded that the general performance and reliability of a relay with respect to surety of contact appears to depend upon two main factors: (1) design and (2) manufacturing processes. Design can reduce or eliminate the problem due to particle contamination by insuring the high contact force and the relatively large amount of contact wipe required to maintain clean contact interfaces. Manufacturing processes can help produce a reliable product by reducing to a minimum the contamination included in each unit during its construction. It is important that those tests which attempt to determine contact reliability maintain operation in the low level area for each total contact operation to obtain the most accurate results; thus, the electrical test parameters must be as low as possible. Four different makes of relays, thought to be represented for hermetically sealed realys, were selected for this study and test. (ASTIA Technical Abstract Bulletin).

121. Dubilier, W., "Latest Developments in Cold Pressure Welding Widen Its Field of Application," Materials & Methods 32, 78-80 (Nov., 1950).

The review contains one section on the application of cold pressure welding in the fabrication of electrical contacts. (ASTM Bibliography and Abstracts on Electrical Contacts).

122. Duke, C. A. and Smith, L. E., "The Technique and Instrumentation of Low-Impedance Ground Measurement," Trans. Amer. Inst. Elect. Engrs. I 77. 767-70 (1958).

The "Selvaz" selective frequency-volt-ampere-impedance meter takes

service supply input and includes a variable magnitude phase balancing-out network, selective frequency voltmeter, switches, valves, resistances, inductances, etc. shown in a detailed schematic wiring diagram. Connections are made to test potential and test current "grounds" and to the substation grounding system. Stray currents are balanced out, interference of power line harmonics prevented, and maximum stability ensured by choice of suitable amplifier constants. A range of sensitivities is provided for ground values from below 0.5 Ω upwards. Five sets have been in satisfactory use by the Tennessee Valley Authority for several years. (Science Abstracts).

123. Duke, C. A. and Smith, L. E., "Instrument Measures Ground Impedance," Elect. World 158, 50 (Dec. 17, 1962).

Determines the resistive and reactive components of an impedance which has relatively long dimensions, such as large station ground system. The instrument is immune to the effects of residual voltages and gives impedance readings directly in ohms of resistance and millihenrys of inductance. (Science Abstracts).

124. Dyson, J. and Hirst, W., "The True Contact Area Between Solids," Proc. Phys. Soc. B 67, 309-312 (April, 1954).

A new method for observing the points of real contact between two solid surfaces is described. A metallized glass surface is pressed into contact with the specimen, the glass surface being deformed locally at the points of contact. The opposite side of the metallized surface is examined through the glass by phase contrast microscopy, the deformation showing bright on a dark background. Deformations of a few Ångstroms in depth are detectable if their lateral extension is above the resolving limit of the microscope. Nominally flat, ground, polished, and lapped specimens of silver steel have been examined. With each specimen true contact was made within regions the sizes and distribution of which were determined by the general undulations of the surface and by the magnitude of the applied load. The differences lay in the distribution of the local contact areas within the general regions. With the polished specimen true contact was made over almost the whole of the general region, but with the ground specimen it was confined to a few isolated areas along the grinding ridges. True contact with the lapped specimens was made at a very great number of areas, each of a few microns in linear dimension. (Science Abstracts).

125. Eichacker, R., "An Impedance Meter with Direct Reading on a Smith Chart," Onde élect. 35, 534-41 (May, 1955). In French.

A generator feeds, through a T-junction and matched attenuators, two identical coaxial lines terminated respectively by the impedance Z_1 to be measured and by a reference impedance Z_r. Directional couplers fitted symmetrically with respect to the ends of the coaxial lines furnish voltages proportional to the components reflected by Z_1 and Z_r. After transformation by a common heterodyne oscillator to a medium frequency and amplification, the amplitudes are compared by means of a moving-coil instrument, corresponding to the reference amplitude, and a mirror galvanometer whose reflected beam gives a luminous spot on a Smith chart. Calibration is effected by short-circuiting the two coaxial lines and adjusting the two deflections to their maximum values by regulating the output of the generator, a potentiometer affording correction for the moving-coil meter. The chart can be rotated and when its real axis is horizontal, the deflection of the spot gives at once the v.s.w.r. A delay line fitted round the periphery of the chart, the ends of which are fed from the two m.f. voltages, after limiting, enables the phase angle of the reflection coefficient to be determined from the voltage-minimum position of a contactor attached to the chart and rotating with it. With this setting of the chart, the value of the unknown impedance or admittance can be read directly from the position of the luminous spot. The frequency range of the equipment is 30-300 Mc/s. The transmission constants of a network may be determined from readings obtained when the input of the network is connected to the end of the measurement line and the output to the measurement line. The various elements of the equipment are described in some detail, with illustrations. (Science Abstracts).

126. Elek, A., "Proving the Adequacy of Station Grounds," Trans. Amer. Inst. Elect. Engrs. I 81, 368-76 (1962).

The definition of ground resistance and ground impedance in the case of alternating currents is discussed. Ground resistance measurements with earth testers are compared with power frequency methods and the errors associated with the location of auxiliary grounds are described. It is emphasized that the ultimate purpose of testing station grounds is to determine touch voltages and potentials arising on communication circuits. Methods are presented to evaluate the adequacy of station grounds, including very large stations. (Science Abstracts).

127. Elistratov, P. S., "Electrical Contact Resistance During Fusion Butt Welding," Avto. Delo. 22, 14-16 (Aug., 1951). In Russian.

Experimental values of the above are broken into component parts. Current density, rate of fusion; and types of welding machine (two types) were the principal variables. Data are tabulated and charted for low-carbon steel. (Battelle Technical Review).

128. Edwardes, H. N., "The Measurement of Balanced Impedance at V.H.F.," Proc. Instn. Radio Engrs. Australia 20, 343-9 (June, 1959).

After a brief survey of existing techniques for the measurement of balanced impedances, a balanced standing wave detector is described with which an accuracy of 3-5% is attainable. The results of measurements of twin feeder parameters, television tuner input impedances and aerial impedances are given. (Science Abstracts).

129. El-Koshairy, M. A. B. and others, "Erosion of Contacts by Arcing. The Effect of Current Waveshape and Other Factors," Proc. Instn. Elect. Engrs. 108A, 70-7 (Feb., 1961).

The effect of the current waveshape on the rate of arc erosion is studied for currents of 180-1090 amp, with contacts of molybdenum, steel and a sintered mixture of tungsten and copper. The amount of arc erosion is found to increase with the current amplitude for a constant arc charge. It is not linearly proportional to either the arc charge or its current amplitude. It increases with the current amplitude at an increasing rate over the range of tests. It is found to be sensitively affected by the contact separation in the millimetre range. (Science Abstracts).

130. Elliott, S. J., "Evaluation of Solderless Wrapped Connections for Central Office Use," Trans. Amer. Inst. Elect. Engrs. I 78, 185-94 (1959).

Laboratory studies involving accelerated ageing tests and field experience since 1950 have provided assurance that properly designed and properly made solderless wrapped connections will perform satisfactorily for 40 years in central office service, which is the criterion laid down by the Bell System of America. The accelerated ageing tests have been based on two types of test-baking at 175° C for three hours, or at 105° C for five months, with and without cycling, and with and without applied vibration of the joint, the criterion being ΔR, the change in resistance of the joint during the test. The resistance measurement is made by the familiar 4-terminal voltmeter-ammeter method, passing 0.1 ampere through the joint for the test, and measuring the p.d. Not more than 1 joint in 10,000 exceeding 0.1Ω is the objective sought. The slower, low-temperature ageing tests was found to be the more reliable test, when both included "plucking" of the joint to vibrate it, but the faster test could be made a satisfactory screening test for a preliminary selection from, e.g. newly designed terminal types to be subjected to the slower test. A mathematical study is included for establishing a criterion parameter $\underline{m}$ from the distribution curve of the results obtained in a test sample, $\underline{m}$ being the arithmetic mean of the grouped distribution of the ΔR arranged in "range-cells", and numerous tables and diagrams are given for expressing the results obtained in actual tests. (Science Abstracts).

131. Elliott, S. J., "Evaluation of Solderless Wrapped Connections for Central Office Use," Bell Syst. tech. J. 38, 1033-59 (July, 1959).

The general reliability objective for solderless wrapped connections has been that they should remain mechanically secure and electrically stable during manufacture, shipment and installation and for 40 years thereafter in actual service. Destructive mechanical tests were used to evaluate the mechanical properties of the connections. Combinations of elevated temperatures and mechanical disturbances were used to accelerate the ageing processes that tend to cause electrical instability. The results of such tests provide considerable assurance that properly designed and properly made connections will perform satisfactorily for 40 years. (Science Abstracts).

132. Epprecht, G. W. and Stäger, C., "The Measurement of Small Reflections in Coaxial Cables and Waveguides," Tech. Mitt. PTT 33, 143-55 (1955). In German.

Various methods are described and results are given for 15 different types of coaxial plugs. Methods of improving the design of the plugs are discussed. (Science Abstracts).

133. Evans, U. R., "Electrical Contacts; the Effect of Atmospheric Corrosion," Met. Ind. 73, 10-13 (July 2, 1948).

Investigations reviewed suggest that two entirely different types of corrosion product can be produced by atmospheric attack and that these two types affect electrical-contact problems in different ways. 31 references. (Battelle Library Review).

134. Eyraud, I. and Bonijoly, P., "Differential Bridge for Impedance and Impedance Deviation Measurements Between 10 kc/s and 10 Mc/s," Câbles et Transm. 12, 148-61 (April, 1958). In French.

Direct-reading bridges for the determination of real and imaginary components of an impedance with an accuracy of 0.01 ohm are described. These devices allow precise measurement of the difference between two impedances and notably that of a cable input impedance deviation compared with a pure resistance or a standard balancing network. They are therefore particularly suitable for determining impedance deviations between different coaxial pairs. They are necessary for accurate balancing-network adjustment and are useful for transient-measuring apparatus and methods. (Science Abstracts).

135. Fairweather, A., "The Closure and Partial Separation of a Metallic Contact," J. Instn. Elect. Engrs. 92, 301-321 (Aug., 1945).

The problems associated with contacts between clean metallic surfaces approaching and separating normally are discussed. The effects encountered in the change of resistance with current and mechanical pressure are investigated and it is shown that the extent of resistance changes is directly related to the mechanical pressure. The unequal wear of the 2 members of a contact pair is discussed, this often being accompanied by transfer of metal from one contact to the other. Experimental methods of investigating contact erosion and metal transfer are described and graphs show the current-voltage and temp.-voltage characteristics of molten metallic bridges. (Science Abstracts).

136. Fairweather, A., "The Behavior of Metallic Contacts at Low Voltages in Adverse Environments," Proc. Instn. Elect. Engrs. 100, 174-182 (July, 1953).

The surfaces of electrical contacts are usually contaminated by foreign layers. Such layers may consist of dust or grease, or of films produced by adsorption, tarnishing, or corrosion. The applied voltage is regarded as "low" when it is too small to initiate conduction by any process analogous to breakdown. The problem in such circumstances is to obtain metal-to-metal contact mechanically. An attempt is made, for the first time, to describe the behavior of a closed contact subjected to corrosion, and the closure processes for a corroded contact, both with and without "wipe." The principles outlined provide some theoretical basis for design and testing techniques. Attention is also given to sliding contacts and, in particular, to the exposed intermittently-operating type: some new approaches to the problems involved are suggested, perhaps the most important being the development of a new technique for the continuous dry lubrication of sliding contacts in mechanical and electrical systems. (Science Abstracts).

137. Fairweather, A. and Frost, E. J., "The Design and Testing of Semi-Permanent Metallic Contacts for Use at Low Voltages," Post. Off. Elect. Engrs. J. 53, 26-33 (April, 1960).

The importance of surface contamination and the effects of different environments on various types of contact are discussed. Methods of contact testing including the use of artificial atmospheres to produce accelerated deterioration are also described. (Science Abstracts).

138. Fairweather, A., Jury, R. L., Lazenby, F., Parker, A. E., Thrift, D. H., and Wright, L. J., "Massacre--A Machine for Automatic Surface Sampling and Automatic Contact-Resistance Evaluation," Proc. Instn. Elect. Engrs. 109A, Paper 3845 M, 210-19, 228-30 (June, 1962).

Studies of the effects of environment on the mechanical and electrical properties of surface films on contact metals involve many measurements of properties, such as contact resistance, for a range of loads applied both with and without an associated surface traction (wipe). It is impracticable, and wasteful of effort, to do such work manually. The machine described does it automatically: ten loads are available and a plate two inches square can be tested at a thousand different places, each observation occupying eight seconds. The test sequence at each

plate is as follows. A probe is lowered gently on to the plate, and when stationary, the contact resistance is measured and classified automatically. The probe is then "wiped" and, again when stationary, a similar evaluation is made. This procedure is repeated for each of seven loads (10, 20, 50, 100, 200, 500 and 1000 g) or until one or other of the two sets of contact resistances falls within a specified range. The remaining three loads can be applied manually when it is necessary to explore a particular load interval in detail. Resistance measurements are made with a 4-terminal bridge arranged so that the open-circuit voltage at the source is about 40-50 mV. A switching unit takes the place of the variable arm in the bridge, and substitutes, in turn, one resistor from a group of five. When the bridge condition passes through a balance as a consequence of bringing a particular resistor into circuit, the event is recorded on one of a group of five meters corresponding to the resistance classification used. (Science Abstracts).

139. Fan, H. Y., "Theory of Electrical Contact Between Solids," Phys. Rev. 61, 365-371 (March 1 and 15, 1942).

The phenomena of electrical contact are examined in detail. The difference between the behaviors of metals and semiconductors is pointed out. It is shown that the density of conduction electrons in a semiconductor can be expected to change appreciably from its normal value which may be important for the explanation of certain phenomena. (Science Abstracts).

140. Fan, H. Y., "Contacts Between Metals and Between a Metal and a Semiconductor," Phys. Rev. 62, 388-394 (October 1 and 15, 1942).

The problem is treated classically with the help of the results of wave-mechanical theory of electron energy states in solids. The potential and electron-density distributions in two bodies near the contact are discussed. The bodies are assumed to be in immediate contact. The problem of a body in vacuum and the problem of two bodies separated by a gap are discussed qualitatively. (Science Abstracts).

141. Favors, H. A., Bloom, R. E. and Fleischer, R. J., "Interference and the R.F.I. Meter," Instrum. Control Syst. 34, 1443-50 (Aug., 1961).

An r.f. intensity meter designed by Stoddart Aircraft is described with block diagram. It can be used for the accurate measurement of natural and man-made interference, both c.w., random and impulsive. A method is described of using the meter with two current-transformer probes to measure the impedance of an a.c. line. Calibration problems are then discussed, and two alternative methods are given for the measurement of low-level r.f. power by a resistance-type bridge having a thermistor in one arm. (Science Abstracts).

142. Feldmesser, K., "New Equipment for Impedance Measurement at v.h.f. 1. The Marconi v.h.f. Admittance Bridge Type TF978. 2. The v.h.f. Bridge Source TF1274 and the v.h.f. Bridge Detector TF1275," Marconi Instrum. 7, 120-127 (Dec., 1959).

143. Fischer, J. F., Jr., Ohta, H. H., and Jakubec, L. G., Jr., Proposed Specifications for Electromagnetic Shielding of Enclosures and Buildings. Genistron, Inc., Los Angeles, Calif., Final rept. on Phase I. AD-284 366 (10 Sept. 62). 116pp.

Effort has been directed toward the compilation of an extensive bibliography and its analysis. This quest for literature resulted in the abstracting of some 144 articles and documents pertaining to electromagnetic shielding. A tabulation of this literature and brief abstracts of each are included. The theoretical shielding effectiveness of various materials has been calculated. The results of this evaluation were used to reduce the number of materials taken under consideration for further investigation. (ASTIA Technical Abstract Bulletin).

144. Flaschen, S. S. and Van Uitert, L. G., "New Low Contact Resistance Electrode," J. Appl. Phys. 27, 190 (Feb., 1956).

Apparent resistivities of high density homogeneous nickel ferrite ceramic specimens were measured as a function of voltage (0.01V to 140V), using various electrodes including those evaporated, fired, painted and rubbed on. Rubbed on indium amalgam gave constant resistivity over the entire voltage range. This was also the lowest measured value, being identical with the true resistivity of the specimen as measured by other means. An indium-gallium alloy had similar properties. (Science Abstracts).

145. Flom, D. G., "Apparatus for Studying Friction and Sliding Electrical Contacts," Rev. Sci. Instrum. 26, 1-4 (Jan., 1955).

The apparatus is designed for tests, if required, in vacuo, and with precise temperature control. It consists of a stainless steel bell-jar with Plexiglas windows. Inside is a rotating cylinder of one of the materials under test, the cylinder being driven through a magnetic coupling from a variable speed 1/6-hp motor outside. The other material under test is attached to a rider and bears against the cylinder under a normal force controlled by a push rod. The rider can be lifted from the cylinder by winding up a nylon thread, again through a magnetic coupling. The friction is measured by means of strain gages attached to the rider holder and indicating the defectional force. Recorded charts of μ against cylinder rotation are shown for brass-copper and steel-steel contacts. (Science Abstracts).

146. Flom, D. G., "Metal Transfer in Sliding Contacts," J. Appl. Phys. 28, 850-854 (Aug., 1957).

Transfer of radioactive silver has been studied quantitatively in sliding contacts containing graphite and metal. The rate of transfer from silver-graphite riders to graphite cylinders is initially high but soon approaches a limiting equilibrium state. The amount of silver transfer increases markedly with surface roughness. Further, the transfer is enhanced by the addition of liquid water to the rider track. Back transfer to the rider has been found to consist mostly of loosely clinging dust in the rider face. Silver transfer to a copper cylinder is much greater than to a graphite cylinder, the difference being roughly twenty-fold. Within the experimental conditions, the transfer/unit time to both graphite and copper cylinders is greater at 1 cm per sec than at 390 cm per sec. (Science Abstracts).

147. Flom, E. G., "Contact Resistance Measurements at Low Loads," Rev. Sci. Instrum. 29, 979-81 (Nov., 1958).

A modification of the fine-wire loop technique for studying surface contact resistances, as developed originally by Savage and Flom is described. The principal change is substitution of quartz fibre for platinum wire as the resilient part of the probe. The contact end of the probe consists of either platinum or gold--other metals could be used as well. An additional improvement is the provision for gradually increasing the applied force between the probe and surface at a low, known rate. This can provide information, not only on the electrical and physical durability of the film, but also on the changing bulk characteristics of the contact junction. Applications in which the quartz fibre probe has been used for studying silver-plated aluminium contacts, gold-plated silver contacts, and copper--Teflon films on copper are discussed. (Science Abstracts).

148. Flom, D. G., "Contact Resistance Measurements at Low Loads," Proceedings of 1958 Elect. Contacts Seminar, Penn. State Univ. (June, 1958).

Results and applications of modifications of the fine-wire loop technique for studying surface contact resistance. Principal modification is use of quartz fiber as resilient part of probe and provision for gradually increasing pressure at known rate. Two types of probes discussed, platinum wire attached by fusion with silver to quartz or 0.7 mm gold sphere fused to quartz. Several applications listed. Primary studies made on silver plated aluminum. No considerations given to RF measurements. Method useful for surface contact analysis.

149. Flom, D. G. and Savage, R. H., "Insulating Films on Metal Contacts," Gen. Elec. Rev. 58, 59-61 (March, 1955).

Probe consisted of 2 mil platinum wire in form of loop. Contact resistance measurements made with potentiometer when known current was passing through insulating film.

150. Fogaras, L., "Contact Resistance Measurements with a.c.," ASEA Journal 34, 9-11 (1961).

Up to now the measurement of contact resistance by means of a.c. has proved to be difficult to accomplish, and generally such measurements have had to be performed with d.c., despite the fact that the conditions with d.c. differ essentially from those with a.c. Recent developments in the field of Hall generators have made it possible to design a simple and practical measuring equipment for a.c. The article describes an equipment of this type developed at the ASEA High-power Laboratory, Ludvika. (ASEA Journal).

151. Foltz, H. L. and Hertz, M. R., "Measurement of Carbon-Metal Contact Resistance," J. Electrochem. Soc. 106, 67-69 (Jan., 1959).

The resistance of a carbon-metal contact and its variation with pressure, was measured, using various metals. The effect of fluorine on the resistance was also examined, in order to decide which metals are most suitable for use in fluorine cells. (Science Abstracts).

152. Freitas, E. A., "Electrical Bonding," Report No. NAI-56-15, Northrop Aircraft, Inc. (9 May 1956).

This report was prepared for design engineers in the aircraft industry and is intended to explain the necessity of adequate electrical bonding and methods of attaining it. Several commercially available instruments for measuring bonding resistance are described. Applicable MIL specs are listed and discussed.

153. Frenkel, J., "On the Theory of Electric Contacts Between Metallic Bodies," J. Exp. and Theor. Physics 9, 489 (1945).

Electrons penetrate the gap between two bodies by thermo-electric emission; image forces lower the potential barriers by an amount inversely proportional to the width of the gap. Thus the electrical conductivity of fine metallic powders and granular films rises with temperature in a way similar to semiconductors. (Science Abstracts).

154. Fricke, H., "Goniometer Measuring Arrangements for High Frequencies," Arch. tech. Messen 283 153-6 (Aug.); 286, 225-6 (Nov., 1959). In German.

Descriptions are first given of the construction of (a) short-circuit, (b) matching types of goniometer and then their application to the measurement of admittance, frequency and phase angle is described in some detail. Numerous references are given to relavent publications. (Science Abstracts).

155. Fricke, H., "Frequency-Independent Measurement of Complex Quotients with the Goniometer," Elektrotech. Z. 81, 422-7 (June 6, 1960). In German.

The fundamental principles of such goniometer measurements are described in detail. The resultant field of a goniometer depends on the ratio of the amplitudes and on the phase difference of the currents of voltages applied to the exciter systems, so that the quotient of two quantities may be determined from the spatial dependence of the search-coil output voltage. From observation of the resultant goniometer field, a working diagram can be derived which permits direct reading of complex quotients from the location and amplitude of the minimum of the search-coil output voltage. Typical equipments for use at low frequencies and in the u.s.w. range are described and experimental results are given. (Science Abstracts).

156. Fuchs, G., Reflections in a Coaxial Cable Due to Impedance Irregularities," Proc. Instn. Elect. Engrs. 99, 121-136 (April, 1952).

The first part of the paper outlines the significance of impedance irregularities in a coaxial cable and develops the relations between the actual irregularities, the curve of input impedance against frequency, and the echo response of the cable to a voltage impulse. The steady-state and transient methods of measurement are then compared theoretically, on the basis of resolving power, and are found to lead to the same result. These theoretical conclusions are proved experimentally by measurements on an artifically faulty cable. Suggestions are made for the application of these results to factory production of cables; in particular the statistical aspect is considered and parameters giving the maximum correlation are discussed. A

simple pulse-testing method, using two spaced pulses, is then described with particular reference to the testing of factory lengths of cable intended for television transmission. (Science Abstracts).

157. Fukuroi, T. and Muto, Y., "Electrical Contact Resistance Between Metallic Surfaces Subjected to Various Treatments," Sci. Rep. Res. Insts. 3, 281-291 (June, 1959).

Contact resistance between two W. rods, which are placed crosswise and pressed together with a pressure from 10 to 100 g, is measured over the temperature range from room temperature down to the boiling point of liquid N. The experiment is performed with the specimen subjected to three kinds of surface treatments: mechanical polishing, electrolytic polishing, and etching. It is found that the contact resistance depends on the contact pressure and varies linearly with temperature, pursuant to the kind of surface treatment. From the experimental results, the contact resistance is considered as consisting of two parts, namely, the convergence resistance and the transition resistance which is independent of temperature. By using these relations, the contact area and distance are estimated under certain assumptions. The relationship between contact resistance and surface condition is discussed. (Science Abstracts).

158. Furkert, W., Gartner, H. and Grabe, G., "Location of Faulty Wire Joints With the Aid of an Infra-Red Detector," Conf. Internat. Grands Reseaux Elect. (France), 1960, Paper 218. 23pp.

A method designed to detect wire joints which have become defective is described. The method, and the limits for its utilization are demonstrated with the aid of results of measurements which were obtained during research carried out in open-air test station for line fittings at high voltage. However, the paper gives indications of actual applications in the operation of lines at medium and at high voltages. A few summaries of results of measurement are given. (Science Abstracts).

159. Gabriel, W. F., "An Automatic Impedance Recorder for X-band," Proc. Inst. Radio Engrs. 42, 1410-21 (Sept., 1954).

A broadband, low-power, automatic impedance recorder of good accuracy has been developed for the X-band frequency range. The instrument will accept any impedance which has an X-band waveguide input and will plot an ink graph of either the impedance or the admittance upon a standard Smith type impedance chart. If the test impedance is one of low mismatch, the instrument can be switched to an expanded Smith chart scale and thus provide greater plotting accuracy near the matched condition. The plane of impedance measurement, or "reference terminals," of the instrument may be located at any point desired along the waveguide transmission line leading to the test impedance and will remain fixed for all frequencies in the operating band. An r.f. impedance circuit utilizing broadband waveguide components extracts the amplitude and phase information which operates electromechanical servos in the amplifier-recorder unit. The components at present in use give an operating bandwidth from 8400 Mc/s to 9900 Mc/s, and the arrangement is such that the system will operate on any incident r.f. power level within the range of about 20 to 250 mW. (Science Abstracts).

160. Gagel, H. and Dittler, H., "Materials for Electrical Contacts," Elektrotech. Z. 73, 292-294 (May, 1952).

The special characteristics of metals and alloys commonly used are reviewed with a summary of their relative advantages and disadvantages. (Instrument Abstracts).

161. Gal'perin, B. S., "The Problem of the Conductivity of an Electric Contact," Zh. tekh. Fiz. 22, 1513-1517 (1952). In Russian.

The theory of spreading cannot be applied to a point-type or separated contact. Expressions for the effective area of an electric contact with convex surfaces may be derived on the assumption of possible conductivity mechanisms of gaps of atomic dimensions, viz. the tunnel effect of facilitated emission of thermal electrons. It is found that the current is mainly concentrated in the zone of approach within which the gaps do not exceed 1 to 1.5 Å, independently of the surface configuration. The calculation also proves that the predominant conductivity mechanism between the metal particles is the tunnel effect. The characteristics of the contact play an essential role in disperse conducting systems. As regards the thermal electron mechanism, the calculation shows that if the work function exceeds 1.5 eV, the tunnel effect will always prevail at the normal temperatures over the thermal electron emission, at least in the interesting range of gap sizes. The apparent predominance of thermal electron emission in the range of very small gaps is only a result of an incorrect application of the theory working with electric image forces to gaps of atomic dimensions and has no physical significance. However, the actual thermal electron emission influences, in certain ranges, the temperature relation of the conductivity of the gaps. (Science Abstracts).

162. Gerber, T., "Properties and Comparative Tests of Relay Contracts," Tech. Mitt. PTT, 34, 1-26 (1956). In French.

Contacts of 18 types were tested in relays under slightly severe conditions. Resistance-operation curves, photographs and material transfer details are given for current-carrying and zero-current operation. High voltage spark tests were also performed. (Science Abstracts).

163. Gerber, T., "Contact Metals and Relay Contacts," Tech. Mitt. PTT 33, 89-114 (1955). In German.

The physical properties of the metals commonly used for contacts are tabulated and discussed. A detailed account is then given of investigations of the relations between experimental values of the contact resistances and the modifications which the surfaces of the contacts undergo during prolonged operation under different loading conditions. The contacts used were: Ag and Ag alloys with Au and W; Au/Ni alloy; Pd; Pt and Pt alloys with Ir and Cu; W. The contacts were operated in Ericsson relays with the contact fingers horizontal, the make and break being about once per sec and the total number of operations about 10^7 in most cases. In the first series of tests the contacts carried a direct current of 80 mA, in the second series no current and in the third series h.v. sparks were passed for 3 minutes between pairs of contacts 2.5 mm apart. Tables and diagrams show the progressive changes of contact resistance in the first two series of tests. Contacts made from a 95/5 Au/Ni alloy showed no change of resistance in the first series, while in the no-current tests the resistance decreased slightly. Micrographs are reproduced which show the condition of the contacts in the first and second series of tests after 10^7 operations and in the h.v. spark tests after 3 minutes. The condition of the various contacts at the conclusion of the tests is described in detail in tables. The results of the tests are discussed. (Science Abstracts).

164. Gerlach, M., "Measurement of the Electrical Properties of Terminals," Elektrotech. Z. 74, 582-6 (Oct. 11, 1953). In German.

A thorough investigation leads to the following requisites for ensuring comparable results in testing terminals: Measurements should be made with d.c. The voltage drop between terminal inlet and outlet should be measured with variously tightened screws. The voltage drop plotted against the torque of the screws is the "characteristic" of the terminal. Temperature relations should be tested by determining heating and cooling curves. Endurance tests should be made with varying loads. The quality of the terminal is determined by measuring the voltage drop between inlet and outlet both in endurance and short-circuit tests. The conductors should always be cleaned in the same manner. (Science Abstracts).

165. Germer, L. H. and Haworth, F. E., "Erosion of Electrical Contacts on Make," J. Appl. Phys. 20, 1085-1109 (November, 1949).

When an electric current is set up by bringing two contacts together, they necessarily discharge a capacitance. If the discharge takes place through an arc before the metallic circuit is established, erosion of the electrodes results. In an l.-v. circuit the occurrence of an arc depends upon the condition of the electrode surfaces and upon the circuit inductance. For "inactive" surfaces, and a voltage of the order of 50, an arc does not occur if the inductance is $>3\mu H$. Surfaces of various

metals can be "activated" by vapors of certain unsaturated organic compounds, and in the active condition they give arcs even when the circuit inductance exceeds the limiting value by a factor of $>10^3$. When an arc occurs at the make of inactive metal surfaces, its energy, of practical interest in l.-v. circuits, is drawn entirely from a charged condenser, is dissipated almost entirely upon the positive electrode, and melts out a crater intermediate in volume between the volume of metal which can be melted by the energy and that which can be vaporized. Some of the melted metal lands on the negative electrode and, with repeated operation, results in a mound of metal transferred from anode to cathode. This transfer is about 4×10^{-14} cm.^{2} of metal per erg. The arc voltage is of the order of 15 v. If the initial circuit potential is > about 50 v. there may be more than one arc discharge, successive discharges being in opposite directions and resulting in the transfer of metal in opposite directions, always to the negative electrode. (Science Abstracts).

166. Germer, L. H., "Arcing at Electrical Contacts on Closure. I. Dependence upon Surface Conditions and Circuit Parameters," J. Appl. Phys. 22, 955-964 (July, 1951).

In a l-v. circuit the occurrence of an arc between approaching electrodes is dependent upon the nature of the surfaces and upon the circuit inductance. For C surfaces, or noble metal surfaces which have been "activated" by operation in various organic vapors resulting in a carbonaceous layer, the limiting circuit inductance is somewhat above 10^3 H which is much higher than the limiting inductance for clean, noble metal surfaces. This activation by organic vapors occurs for noble metals only and for certain vapors, for example, benzene derivatives. In the case of Ag and benzene vapor, it has been shown that the activation is due to adsorption of benzene onto a greasy surface layer and its decomposition there by the heat of subsequent closures. A metal surface, which has been activated by organic vapor, remains active indefinitely if there is no arcing at the surfaces; but with continued operation and accompanying arcing, the activating material is burned away, and the surface returns to the inactive condition if no activating vapor is supplied. Arc voltages, which are independent of current and of ambient gas, as far as tested, have been measured for a number of metals and for C; the arc voltage for C is quite erratic in the range between 20 and 30 v., but for each of a number of metals the arc voltage is steady. Arcing at noble metal surfaces, similar to that induced by carbonaceous material from organic vapors, can be produced also by insulating particles or insulating films. The active condition gradually disappears with continued arcing; there is a steady supply of insulating material to the surface. The minimum arc current has been measured to be 0.6 A for active Ag and for C, and 0.03 A for inactive Ag. These are the currents at which an established arc is extinguished. (Science Abstracts).

167. Germer, L. H., "Arcing at Electrical Contacts on Closure. II. The Initiation of an Arc," J. App. Phys. 22, 1133-1139 (Sept., 1951).

The capacitance of the plates of an oscilloscope charged to 35 or 40 v. is discharged repeatedly by approaching electrodes of carbon, active silver, and inactive silver. Facts about the discharges, which are arcs of very short duration, are inferred from resulting open-circuit potentials and

calculated electrode separations. The separation at the first arc varies in different experiments but corresponds on the average to a nominal electric field of 0.6×10^6v. per cm. for carbon or active silver and to 2×10^6v. per cm. for inactive silver. Each arc is initiated by a very small number of field emission electrons. The hypothesis that a single electron may perhaps be sufficient is consistent with observations at later stages of each closure when the electrodes are closer and the field much higher. The earlier observation, that the potential across a short arc is constant and independent of current, is not true if the arc time is sufficiently short. For active silver a time comparable with 2×10^{-8} sec. is required to establish the steady arc voltage characteristic of later stages of arcs which last longer than this. The initial time during which the potential is decreasing toward its final steady value is 100 x the transit time of a silver ion across the gap. (Science Abstracts).

168. Germer, L. H., "Physical Processes in Contact Erosion," J. Appl. Phys. 29, 1067-82 (July, 1958).

The various causes of the erosion of noble metal contacts are now isolated and understood. They give adequate interpretation of the sign of erosion under various circuit conditions, and of the space distribution of the eroded metal, as well as quantitative agreement with measurements of erosion in repetitive tests. Electric arcs are the chief cause of erosion, although at breaking contacts glow discharges are important under certain circumstances, and at higher currents bridge erosion is significant also. The arcs are of two types, "anode arcs" which erode the anode predominantly, and "cathode arcs" which erode the cathode. Anode arcs occur at small separations, and cathode arcs at large separations. The metals studied were palladium and silver, which have different characteristics because of their different electrical conductivities and also because of the chemical reactivity of silver. The erosion of these metals in the inactive condition, by weighing the contacts before and after many repetitive operations, is of the order of $4 \times 10^{-14} cm^3/erg$ in anode arcs and less than this by a small factor in cathode arcs, on break as well as on closure. In a glow discharge only the chemically active metal silver is appreciably eroded and its erosion is negligible unless the current density results in a glow of the abnormal type. Activation produced by organic vapours often changes the magnitude of the erosion per unit of arc energy and sometimes its sign, these effects being probably attributable to shielding one of the contacts by carbon lying on it as well as to the greater separations at which arcs occur between active surfaces. (Science Abstracts).

169. Germer, L. H. and Smith, J. L., "Activation of Electrical Contacts by Organic Vapors," Bell System Technical J. 36, 769-812 (May, 1957).

Unreproducibility of earlier work on the erosion of relay contacts has been traced to the effects of organic vapors in the atmosphere. Carbon from decomposition of these vapors greatly alters the conditions under which an electric arc can be initiated and can be sustained. The importance from the standpoint of erosion comes from the fact that for many circuit conditions contacts activated by this carbon can not be protected against severe arcing by any conventional capacitance-resistance network. Investigations which have enabled us to understand the activation of contacts by organic vapors are reported. (Science Abstracts).

170. Gesteland, R. C. and Howland, B., "Bridge for Measuing the Impedance of Metal Microelectrodes," Rev. Sci. Instrum. 30, 262-4 (April, 1959).

Describes an a.c. bridge for measuring the series components of high-impedance metal-liquid interfaces. The real and imaginary components of the impedance may vary over a wide range. All frequency-independent residual error-introducing elements in the measuring circuit may be balanced out through a single square-wave initial balance step. This allows accurate, direct-reading measurement of the unknown. The bridge design is based upon superposition of frequency-independent bridge circuits. (Science Abstracts).

171. Gex, Robert C., Thermal Resistance of Metal-to-Metal Contacts: An Annotated Bibliography. Lockheed Aircraft Corp., Sunnyvale, Calif., Special Bibliography no. SB-61-39: 3-34-61-6. AD-263 181 (July, 1961). 20pp.

Forty-four annotated references on heat transfer through metallic contacts are included. Emphasis is placed on thermal contact resistance in a vacuum. Welded and bonded joints are not included. Most of the information abstracted relates to the technologies of aircraft structural design and nuclear reactor design. The literature sources used were: (1) Applied Mechanics Review (1948-1961), (2) Engineering Index (1940-1961), (3) NASA & NACA indices (1950-1961), (4) Nuclear Science abstracts (1951-1961), and (5) Lockheed Missiles & Space Co. (ASTIA Technical Abstract Bulletin).

172. Giznzini, A., "Silver as Contact Material in Low-Voltage Apparatus for Motor Control," R. C. 55 Riun. Assoc. Elettrotec. Ital. Bellagio, 1954, Vol. 42, Fasc. 2, Paper 144, (1955). 6pp. In Italian.

After describing the requirements for electric contacts, a discussion follows on the test results on various alloys and sintered materials. It is concluded that silver gives the best all-round results. (Science Abstracts).

173. Gibbings, D. L. H., "An Alternating-Current Analogue of the Kelvin Double Bridge," Proc. Instn. Elect. Engrs. 109C, 307 (1962).

In connection with a project for an absolute determination of the ohm, the author has developed an a.c. 4-terminal resistance bridge. This new bridge is analogous to the Kelvin double bridge, but resistive ratio arms are replaced by transformer ratio arms and indictive dividers. Besides the benefits of impedance matching and ease of amplification which the use of alternating current confers, the replacement of resistive ratios by inductive devices brings great advantages in accuracy and stability of ratio. In the bridge described here, the ratio is believed to depart from the nominal value of 10:1 by little more than 2 parts in 10^7 over the frequency range of 330 rad/s (52.5 c/s) to 33,000 rad/s (5.25 kc/s).

174. Gol'dberg, I. V., "Inspection of Contact Connections by Semiconductor Thermoresistance," Energetik 6, 26-27 (Sept., 1958). In Russian.

Description of a simple, but very sensitive instrument for measuring surface temperature of current carrying parts of electrical equipment with semiconductor thermoresistance. (Battelle Technical Review).

175. Golding, J. F., "Impedance Bridges," Brit. Commun. Electronics 5, 104-109 (Feb., 1958).

Various types of impedance bridge and their applications are described. Brief specifications of representative bridges commercially available in U.K. are presented in a table. (Instrument Abstracts).

176. Golding, J. F., "Transformer-Ratio-Arm Bridges," Wireless World 67, 329-335 (June, 1961).

The transformer-ratio-arm system is described in detail. The suitability of the bridge for particular measurements of capacitance, inductance and resistance is considered. (Instrument Abstracts).

177. Goldmann, J. B., RF-Frequency Interference and Shielding: An Annotated Bibliography. Lockheed Aircraft Corp., Sunnyvale, Calif., Rept. no. 8-19-62-2. AD-296 352 (Sept. 62). 33pp.

This annotated bibliography is primarily concerned with isolation of radio frequency interference by use of filters, shielding effectiveness, and means by which radiation emission can be checked, controlled, or reduced. Other areas for investigation were the advisability of change from single to double shielding and twisted pair to single wire. The literature surveyed covers the period 1960-61. (ASTIA Technical Abstract Bulletin).

178. Golubeva, V. P., "Bolted Joints of Copper-Aluminium," Elekt. Stantsii 12, 42-8 (Dec., 1958). In Russian.

States that in recent times there has been a tendency to depart from bolted connections in favour of welded or pressure joints. This has resulted from the need to avoid corrosion due to electrochemical potentials by the failure of the bolts under short-circuit conditions. In order to overcome these difficulties and because of its cheapness, investigations and experiments were carried out with bolted connections. It was found that bolted connections were satisfactory provided certain precautions were taken. Amongst those were selection of a suitable size of bolt and type of spring-washer to ensure that the pressure on the aluminium can be controlled. It is also recommended that the extremities of the busbars are either coated with graphite or protected against corrosion by copper-plating on zinc. The experiments performed, and results obtained under various conditions, are tabulated and explained in detail. (Science Abstracts).

179. Gordon, A. N. and Sondheimer, E. H., "The Evaluation of the Surface Impedance in the Theory of the Anomalous Skin Effect in Metals," Appl. Sci. Res. B3, 297-304 (1953).

A simple method for obtaining series expansion of the integrals. Results agree with an intuitive procedure. (Science Abstracts).

180. Gosland, L., "Performance of Joints in Steel and Nonferrous Conduits and Fittings," Rep. Brit. Elect. Res. Assoc.,Rep. V/T119(1955).

It is expected that the use of electrical conduit in wrought Al alloy, and

fittings in wrought or cast aluminum alloys and Zn alloys, will increase and some tests have therefore been undertaken on the maintenance of electrical continuity of screwed joints between the various metals and between these metals and steel. (Science Abstracts).

181. Graff, H. J., Peacock, J. M. and Zalmans, J. J., "Development of Solderless Wire Connector for Splicing Multipair Cable," Bell Syst. tech. J. 42, 131-53 (Jan., 1963).

Describes the development and laboratory testing of a new high-reliability solderless connector for splicing cable conductors. It includes discussion of the physical parameters which influence the performance of electrical contacts in general. The experimental and analytical techniques which evolved as part of this project permit important reductions in the amount of experimental data required to make reliability and aging predictions, and should be useful in other problems dealing with the appraisal of electrical contacts. (Science Abstracts).

182. Grainger, H. B. and Watkins, R. J., "Aluminium Busbars," Engineering 184, 744-8 (Dec. 13, 1957).

The development of an aluminium alloy to withstand mechanical and electrical stresses and having acceptable electrical conductivity is described. A method for achieving stable joints of low resistivity using a chemical jointing compound, is given. The Kynal M38 alloy has the following properties: ultimate tensile strength, 13 tons/in^2; 0.1% proof stress, 10.5 tons/in^2; elongation 10%; conductivity, 55%. The jointing technique, tests on the joints and recent installations are outlined. The performance of joints exposed to industrial atmosphere at various current loading is tabulated. (Science Abstracts).

183. Grebenkemper, C. J. and Hagen, J. P., "The High Frequency Resistance of Metals in the Normal and Superconducting State," Phys. Rev. 86, 673-9 (June 1, 1952).

The h.f. resistance of Pb, In and Sn has been measured at frequencies in the vicinity of 9000 Mc/s using resonant cavity techniques. Preliminary measurements on Sn at 24,000 Mc/s also have been made. The experimental techniques and measurement procedure are described. The effect of surface finishes is discussed for both the normal and superconducting regions. Data for the normal state are in general agreement with the Reuter-Sondheimer theory of the anomalous skin effect. The h.f. resistance in the superconducting region was found to vary with frequency as the three-halves power rather than the predicted variation of the second power. (Science Abstracts).

184. Greenwood, J. A. and Williamson, J. B. P., "Electrical Conduction in Solids. II. Theory of Temperature-Dependent Conductors," Proc. Roy. Soc. 246, 13-31 (1958),

The experiments in PtI on the behaviour of the contact between metals when large currents pass the interface have yielded results which cannot be explained by the classical theory of constriction resistances. In an attempt to provide an account of this anomalous behaviour a new mathematical treatment of the general problem of the electrical heating of conductors has been developed. This treatment gives, under the appropriate conditions

a concise derivation of all the main results of the accepted theory. The new treatment is applied to the calculation of the spatial distribution of current for a particular shape of conductor, one which is relevant to many resistance welding processes. The predictions agree accurately with experimental data obtained from the examination of a series of welds. The theory is then applied to the special case of the electrical contact between gold pieces and shown to offer an explanation of the anomalous behaviour mentioned above. Good agreement is demonstrated between the theoretical predictions and the experimental results. (Science Abstracts).

185. Gronlie, L. and Seljeseth, H., "Determination of Earth Conductivity by Measurement at Higher Frequencies," Conf. Internat. Grands Reseaux Elect. (1958), Paper 323, 6pp.

Earth conductivities may in some cases -- as a matter of convenience -- be measured at higher frequencies, as a substitute for measurements at power frequency. Gives a brief description of the measuring arrangement and a comparison of values of earth conductivities measured at 50 c/s and at higher frequencies. (Science Abstracts).

186. Gross, E. T. B., "Bibliography of Relay Literature," Trans. Amer. Inst. Elect. Engrs. III 74, 45-7 (1955).

187. Gruber, E., "Mechanical and Electrical Contact Between Rough Surfaces," Elektrotech. Z. 80, 745-8 (Nov. 1, 1959). In German.

A mathematical representation of a rough surface is proposed and is applied to two surfaces in contact. The way in which the electrical resistance of the contact varies with pressure is calculated and is found to agree with experiment. (Science Abstracts).

188. Gunn, J. B., "A Simple Bridge Circuit for the Accurate Measurement of Pulse Impedance," J. Sci. Instrum. 33, 364 (Sept., 1956).

The bridge uses a one-inch c.r.t. (type 1CPI) as balance detector, and the bridge voltage (400-2000 V, duration 0.5μs) provides the h.t. supply for the tube. The cathode is connected to the earthed corner of the bridge, and the negative terminal of the pulse generator is also earthed. The Y plates are connected in the unearthed diagonal of the bridge, and the sensitivity is 0.5 mm deflection for 1% unbalance. The c.r.t. anode is coupled to one Y plate. The X plates are not used. The ratio arms are 3/4 W high-stability carbon resistors, 100Ω each, and the variable arm consists of h.t. carbon resistors with a carbon potentiometer for fine adjustment. Use of a pulsed supply for the c.r.t. necessitates fitting a wire gauze to the outside of the screen to obtain satisfactory focusing. The gauze is connected to the pulse generator positive. The bridge can be used with 0.1μs pulses, and the characteristic impedance of 10m of coaxial cable can be measured to three significant figures. (Science Abstracts).

189. Gwyn, C. B., Jr., "Electrical Contacts. I.," Metals and Alloys, 1318-1323 (May, 1945).

Describes the metallic elements which are used as constitutents of electrical contacts and discusses the value and present application status of each. After considering the properties of about thirty elements a short list is drawn up of those elements which meet the requirements of electrical contact. The list includes W, Ag, Pt, Mo, C-impregnated materials and Cu alloys. (Science Abstracts).

190. Gwyn, C. B., Jr., "Composite Electrical Contact Assemblies," Electrical Manufacturing 58, 137-142 (Sept., 1956).

I. Illustrates clad contacts with two or three metals and shows the improvements in performance, fabrication, cost savings and flexibility in the choice of contact and base plate materials. In this manner, the electrical, thermal and mechanical requirements can all be considered. Several methods of bonding the contact materials to the base metal are also described. II. Illustrates assemblies of wire, rod and weldable type semihollow balls or beads; clad screw-type contacts; stapled contacts; and the new projection welding button contacts. (ASTM Bibliography and Abstracts on Electrical Contacts).

191. Haines, M. G., "The Inverse Skin Effect," Proc. Phys. Soc. 74, 576-584 (Nov. 1, 1959).

The axial current density in rigid or radially expanding conductors was calculated as a function of radius and time for an infinite cylindrical conductor. The calculated current distributions in some cases bear no resemblance to the normal skin effect.

192. Halstrøm, H. L., "Some Comments on the Tarnishing of Silver Contacts," Teleteknik 4, 29-39 (1960).

Describes a series of experiments concerning the tendency of various silver alloys to tarnish when used as relay contact material. Taking the effect of exposure to hydrogen sulphide as a measure of resistance to corrosive attack, the results of these experiments can be summarized as follows: Silver-silicon is as corrosion-resistance as silver. A thorough degreasing treatment renders the alloy extremely susceptible to the sulphur compounds present in the atmosphere, but this susceptibility can be diminished considerably by coating the metal with a very thin film of oil. As to surface treatment, the same applies to silver-copper; but there are definite indications that the good properties of this alloy as a contact metal can be ascribed to the fact that the pressure required to shape the material into rivets tends to so deform the material as to leave a surface which seems to consist of pure silver. It is therefore important that the press tools should be shaped with a vie to producing this effect to the greatest possible extent. (Science Abstracts).

193. Hammerli, S., "Problems in High Frequency Electrical Contacts," Bull. Assoc. Suisse Elect. 47, 1194-204, 1217-19 (Dec. 22, 1956). In German.

To elucidate the problems peculiar to high frequency electrical contacts carrying large currents experiments have been made with electromagnetically controlled commutators. Some general recommendations for their construction are deduced and the precautions necessary for reducing electrical and mechanical wear are discussed. (Science Abstracts).

194. Hanson, C. B. and Henderson, D. C., Radio Frequency Impedance Measurements of Nickel--Cadmium Combination Plating on Aluminum Alloy Surfaces for Electrical Bonding, and Anti-Corrosion Finish. Douglas Aircraft Co., Inc., Santa Monica, Calif., Rept. no. SM-43482. AD-299 703 (13 Mar 63).

195. Hariharan, S. and Stuart, W. S., "A New Method of Measuring Very Small Standing Waves in Waveguides," J. Instn. Telecomm. Engrs. 7, 149-52 (May, 1961).

In this method a short piece of waveguide containing a small probe is introduced into the system. This probe causes a reflected wave which will augment the reflection from the termination. Hence the standing wave becomes very large and it can be easily measured by the standing wave detector. From this the small reflection of the termination or mismatch can be easily calculated. (Science Abstracts).

196. Harman, G. G., "Hard Gallium Alloys for Use as Low Contact Resistance Electrodes and for Bonding Thermocouples into Samples," Rev. Scientific Instruments 31, 717-720 (July, 1960).

A new family of low contact resistance electrodes is described. These are hard alloys of gallium, prepared at room temperature in a manner similar to that of dental amalgams. They may be packed into cavities in semiconductors or in some cases applied to a flat surface and allowed to harden under pressures. These alloys can also be used to bond wires and thermocouples into samples. The maximum operating temperatures range from 250° to about 900° C for various alloys. The electrical characteristics, when used on ferrites and controlled valency semiconductors, are similar to those of the frequently used semi-liquid indium-mercury and indium-gallium electrodes. (Science Abstracts).

197. Harrick, N. J., "Determination of the Semiconductor Surface Potential Under a Metal Contact," J. Appl. Phys. 32, 568-70 (April, 1961).

It is shown that, through the use of the infrared absorption technique to measure the added carrier density in a semiconductor bulk adjacent to a metal contact coupled with simultaneous measurement of the floating potential of the contact, a reliable determination of the semiconductor surface barrier height under the metal contact can be obtained. (Science Abstracts).

198. Harrison, L. H., "The Effect of Reactive Components in the Measurement of Grounding Circuits," Applic. and Industr., 340-5 (Nov., 1953).

Results of earth impedance tests indicate that the impedance of earth circuits appears to vary inversely as the frequency; the author therefore suggests that such tests should be made at system or apparatus frequency. Details of test procedure and curves of results are given together with an extensive discussion. (Science Abstracts).

199. Hartshorn, L., "Precision Electrical Measurements," Nature 175, 57-58 (Jan., 1955).

National Physical Laboratory symposium review. Held on Nov. 17-20, 1954.

200. Harvey, H. F., Jr. and Dawson, E. J., "Aluminum for Marine Switchgear," Trans. Amer. Inst. Elect. Engrs. 75, 134-142 (1956).

Temperature-rise tests were made on various types of joints, silver plating and red glyptol lacquer giving best results. A saving of 57 per cent weight over copper and steel can be realized, or 63 tons in each aircraft carrier without extra cost. Comparisons with copper, enclosed power and lighting panels, typical construction and tabulated sizes for 200 to 3600 amp aluminum busses, welded and bolted frameworks, optimum grades of alloy to withstand shock and vibration, fault currents up to 100,000 amp, the use of expanding washers, results of inspection after 17 yr of service, etc., are dealt with. (Science Abstracts).

201. Haug, A., "A Resonance Method for Impedance Measurement with Ultra-Short Waves," Z. Angew. Phys. 2, 330-1 (1950). In German.

A method is developed for dm- and cm-waves which avoids the labour and tedium of standing-wave measurements. The procedure consists essentially of adjusting the Lecher-line to resonance and then to the 0.707-value. The theoretical basis shows that two measured line lengths give immediately the sign of the reactive term while a further simple calculation yields the exact value of the impedance in cartesians. A feature of the method is that the result depends only on differences of line length and not on absolute values. (Science Abstracts).

202. Heller, F., "Compression Wye Splicing to Insulated Aluminium," Trans. Amer. Inst. Elect. Engrs. III 73, 1218-23 (1954).

Increasing Cu prices make Al conductors for underground cables economic and necessitate Cu-Al joints. Temperature differences are minimized since the Al connectors will run at a lower temperature than the Cu within them. Corrosion troubles are eliminated by taping the joint to complete watertightness. Test results showing temperature rise and resistance of joints are given. (Science Abstracts).

203. Henderson, W. L., "The Effective Area of Static Contacts," Electrical Contacts (1961), papers presented at the engineering seminar on electrical contacts, June, 1961, at the Pennsylvania State University.

A method of determining effective area of static electrical contacts. Method consists of measuring reduction of joint loading after temperature cycling (room temp--212°F--room temp in 30 min.). From this data effective contact area can be calculated. Special strain gage apparatus was used to determine joint force. Some tests results on 1/4 x 2 in determining following: (1) No. and size bolts required, (2) amount of overlap, (3) effect of joint surface preparation, (4) effect of force and area on joint life. No frequency effects included, but method may be useful for determining contact area.

204. Hentsch, A., "Recent Investigations and Developments in the Field of Electrical Contact Material," Elektrie 16, 149-52 (May, 1962). In German.

Extracts from a review given at the conference "Contact Materials in Electrical Engineering" of the Deutschen Akademie Wissenschaften, Berlin.

Describes problems and progress in contact materials, with particular reference to contact resistance, metal transfer between contacts, and stratification. (Science Abstracts).

205. Hercules, Wendell L., Shielding Against RF Energy. Armed Services Technical Information Agency, Arlington, Va., Rept. no. ARB-13355 (4 Nov 62).

A bibliography is presented of references concerning the shielding of buildings, interior spaces, equipment, and explosives from radio-frequency energy. (ASTIA Technical Abstract Bulletin).

206. Hilgarth, G., "The Limiting Current in Static High-Current Contacts," Elektrotech. Z. 78, 211-217 (March 11, 1957).

An investigation of the factors which determine the maximum current which can be passed through a static contact without melting the contact faces, with particular reference to large currents (up to 50 ka) of short duration (down to 10^{-5} s). (Science Abstracts).

207. Hill, L. G., "Volt Drop on Aluminum Conductors," Elec. J. 162, 34-35 (Jan. 2, 1962).

Concerns aluminum cables with crimped terminations and anomalous voltage drops measured along the cable. The phenomenon is attributed to inter-strand resistance due to the oxide film and is explained by reference to a simple hypothetical case. (Science Abstracts).

208. Hill, L. G., "Differential Expansion of Conductor Terminations," Elect. Times 135, 125-8 (Jan. 22, 1959).

In recent years the use of aluminium lugs attached to aluminium cables by crimping techniques has been accompanied by incidents leading to complete burn-out of the lug. Such incidents have led to a distrust of aluminium as a suitable material for lugs on aircraft or for busbars. The causes leading to failure are examined and suggestions are made regarding certain basic requirements which if met will ensure that aluminum lugs and busbars give adequate electrical service under the most severe thermal cycling conditions. (Science Abstracts).

209. Hill, J. J. and Miller, A. P., "An A.C. Double Bridge with Inductively Coupled Ratio Arms for Precision Platinum-Resistance Thermometry," Proc. Instn. Elect. Engrs. 110, 453-8 (Feb., 1963).

A simple double bridge with inductively coupled ratio arms for precision resistance thermometry is postulated, and the advantages to be gained from the accuracy, stability, low temperature coefficient, high input impedance and low output impedance of such ratio arms are considered. The equation of bridge balance is examined, and it is shown that the errors in measurement due to the resistance of the potential leads of the thermometer can be reduced to 0.0001°C for any temperature change between -100°C and +100°C and are unlikely to exceed 0.0003°C over the range -183°C to +630°C. A double bridge having eight decade dials and operating at 400 c/s has been constructed, and the details are given. The errors of voltage division within the ratio arms are less than 2 parts in 10^7, and the input imedpance is approximately 650kΩ. (Science Abstracts).

210. Hitchcox, G., "Extending the Limits of Resistance Measurement Using Electronic Techniques," J. Brit. Instn. Radio Engrs. 16, 299-309 (June, 1956).

A discussion of devices and techniques suitable for inclusion in commercial instruments. A description is given of the basic ohmmeter in its two dual forms, and three low resistance systems, two using direct and one alternating test currents. A novel instrument is also described which can measure very low resistance using pulsed test currents thermal dissipation in the test sample. At the very high resistance end of the range where extension has been much greater, the three principal systems are discussed, together with the application of modern devices such as differential constant-current generators, electronic stabilizers, dynamic capacitor modulators. A detailed description is given of a widely-used general purpose commercial megohmmeter. (Science Abstracts).

211. Hoffmann, D. C., "Grounding of D.C. Structures and Enclosures," Trans. Amer. Instn. Elect. Engrs. II 80, 106-12 (1961).

The advantages and disadvantages of high- and low-resistance earthing of d.c. structures and enclosures are presented and guide rules are set forth for use in the design of new installations. A short bibliography and a discussion are added. (Science Abstracts).

212. Hoge, H. J., "A two-E.M.F. Method for the Comparison of Resistances," Rev. Sci. Instrum. 25, 902-7 (Sept., 1954).

A method of comparing resistances is described in which two sources of e.m.f., each with an associated dropping resistor, are connected in series with two resistors to be compared, in such a way that the latter are not adjacent. The circuit may then be adjusted so that the potentials at the two ends of one of these resistances are equal to the potentials at the corresponding ends of the other resistance while both carry the same current. Convenient means of detecting and adjusting to this condition are described. The circuit may be used as an alternative to either the d.c. or the a.c. bridge. The method is suitable for work of either high or low accuracy. Its chief advantage over methods now in use is that it permits the continuous observation or recording of resistance without error due to uncontrolled changes in the resistances of the connecting leads. Readings are obtained directly, without the necessity of averaging or otherwise mathematically combining the results of more than one observation. If desired, more than two resistances to be compared may be included in the circuit, provided that they are alternated with an equal number of e.m.f.'s and associated dropping resistors. (Science Abstracts).

213. Holm, R., aided by Holm, E., "Electric Contacts Handbook," Springer-Verlag, Berlin (1958). 522 pp.

This is a completely rewritten edition of the authors book on electric contacts. It contains five parts. Part I.--Stationary Contacts--treats the theory of constriction resistances including their dependence on the heating by the current and on the time of heating. There are also chapters about films on contact materials, about their growth and fritting (an electric breakdown) of such films. Chapters are devoted to microphone phenomena, contact noise and to contacts with semiconductors. Part II.--Sliding

Contacts--After an extended treatment of friction (including the case of boundary lubrication) and wear, follow chapters dealing with the performance of carbon brushes on current collectors and a discussion of commutation problems. Part III.--Electric Phenomena in Switching Contacts--discusses first arcing in switching contacts and the means to quench the arcs. Several chapters are devoted to the wear at arcing and also to the so-called bridge material transfer. Other chapters concern the application of statistics in the study of contacts and to the choice of contact materials for different purposes. Part IV.--is a history of earlier contact investigations. Nine appendices give a survey of subjects which are of importance for the contact theory without directly belonging to it; for instance, the theory of hardness; electric conduction in solids; the tunnel effect; structure; electric and thermal conductivity of carbons and a general, partly new, theory of the electric arc particularly such arcs which appear in switches.

Finally, tables give material constants which are valuable for calculations about contacts. (ASTM Bibliography and Abstracts on Electrical Contacts).

214. Holm, R., "Electric Contacts," Hugo Gebers Forlag, 396 (1946).

The book is divided into four main parts. The first part discusses the problems concerned with stationary contacts, or contacts which are in the closed position. In this section he discusses such important points as contact resistance, the apparent and real contact surface, temperatures in contacts, electrodynamic and electrostatic forces in contacts, elasticity, hardness, properties of thin and thick surface films and other special features. Each of these items is considered in detail with enough test data or practical information to furnish direct use to be made of the results.

The second part of the book considers sliding contacts such as those on electrical machines. This section is opened with a detailed consideration of hydrodynamic and boundary layer friction. The effect of passing current through the sliding contact surface is considered and contact resistance, arcing, wear, and commutation are discussed. The section on commutation is brief, but the background for further consideration of this problem is given.

The third section presents the electric phenomena in switching contacts. The theory of the electric arc and its application to contact problems is considered in detail. The characteristics of different types of circuits with respect to circuit interruption are presented. The physical basis of transfer of material is described and illustrated.

Part four gives a brief history of development of the physics of electrical contacts. The investigators who contributed to the progress made in this field are mentioned. (ASTM Bibliography and Abstracts on Electrical Contacts).

215. Holm, R., "Temperature Development in a Heated Contact With Application to Sliding Contacts," J. Appl. Mech. 19, 369-374 (Sept., 1952).

Applications of above are made to a contact that is heated by electrical current and to circular or oval heat sources (for example, friction-heated sliding contact surfaces), stationary or moving on the face of a semi-infinite body. Graphs. (Battelle Technical Review).

216. Holm, R., "The Electric Tunnel Effect Across Thin Insulator Films in Contacts," J. Appl. Phys. 22, 569-74 (May, 1951).

Existing calculations on the tunnel effect through thin films in contacts apply to very weak and very strong electric fields. The present paper completes the picture by the treatment of intermediate cases, which are important for many contact applications. (Science Abstracts).

217. Holm, E., Holm, R. and Shobert, E. I., II, "Theory of Hardness and Measurements Applicable to Contact Problems," J. Appl. Phys. 20, 319-327 (April, 1949).

The ball indentation method is recommended for the determination of real contact area. Hardness is defined as the ratio between the contact load and the mouth area of indentation. Variation of hardness with geometric and metallurgical conditions and the relation between hardness and yield point are discussed. Data are tabulated and plotted. 10 references. (Battelle Library Review).

218. Holm, R., Calculation of the Temperature Development in a Contact Heated in the Contact Surface, and Application to the Problem of the Temperature Rise in a Sliding Contact," J. Appl. Phys. 19, 361-366 (April, 1948).

The temperature is calculated in two cases: (1) A circular area on a semi-infinite body heated at a constant rate from the time t=0. (II) A sliding contact, the heat, which is generated by friction, being limited at every point to the time of contact. Observations on the temperatures in bimetallic sliding contacts, indicating the contact temperature rise by means of a thermoelectric current, are compared with the calculations. A fairly good agreement is found. (Science Abstracts).

219. Holm, R., "Technical Physics of Electrical Contacts," ETZ 62, 633-637 (July 17, 1941). In German.

Absolutely clean metallic surfaces can only be established and maintained in a vacuum, and when such surfaces are pressed together, effective contact is limited to isolated spots. In air, metallic surfaces are covered with a film of oxides, chlorides, etc. and usually lubricated. The effects of these phenomena on contact resistance, the narrowing of the current path and the breakdown of the surface film, are discussed. Reference is made to the breakdown of thicker films (coherer resistance), and contact pressure, deformation of surface, heating effects, and sliding contact are discussed. (Science Abstracts).

220. Holm, E., "Contribution to the Theory of the Brus.-Collector Contact," Trans. Am. Inst. Elect. Engrs. III 78, 431-438 (1959).

Carbon brushes moving on a copper collector produce resisting films which, if a current is to flow, must be penetrated electrically, producing conducting spots. In consequence, the contact voltage depends largely on these films. Their properties are studied in detail. (Science Abstracts).

221. Holm, E. and Holm, R., "The Transfer of Matter at Break of Contact, in the Case of Silver and of Platinum," Z. Angew. Phys. 6, 352-61 (Aug., 1954) In German.

The transfer of matter was measured over a wide range of circuit parameters, and was found to be expressible as the sum of three terms. The first term, due to the asymmetrical rupture of the molten bridge, was proportional to the square of the current at rupture; the second and third, due to transfer during the initial (plasma-free) stage of the arc, and to the later stage, were proportional, respectively, to the quantity of electricity which passed during the two stages. In the case of Pt, the nature of the surrounding gas had a marked effect, the cause of which is discussed. (Science Abstracts).

222. Hou, S. and Kurokawa, K., "Research on Contact Points by Ballistic Wattmeter, Part I," J.I.E.E.J. 68, 144-148 (1948). In Japanese.

223. Houldin, J. E., "Impedance-Measuring Equipment for the 50-500 Mc/s Range," Proc. Instn. Elect. Engrs. III 99, 389-99 (Nov., 1952).

The theory and operation of an equipment developed for laboratory use in the frequency range 50-500 Mc/s is described. The principle of the equipment is to compare the modulus of any impedance with that of a standard impedance, namely a 100 Ω 0.1 W resistor mounted so as to keep the lead length constant and at a minimum. From four values of impedance moduli determined experimentally the resistive and reactive components of the unknown can be calculated. This generalized method of determining an unknown can be simplified for particular, and important, cases, such as the measurement of high- and medium-value resistors, inter-electrode impedances of valves, inductances, capacitances. Impedances in the range 1-100 000 Ω can be determined. The error in the measurement of the modulus of an unknown impedance is $<\pm 5\%$, whilst that of the phase angle varies with the value of impedance being measured. Examples of measurements made on resistors, crystal valves, and short-circuited coaxial transmission lines are given. (Science Abstracts).

224. Hrynczuk, J., "Contribution to the Analysis of the Phenomenon of Surge Skin-Effect," Arch. Elektrotech. 8, 521-6 (1959). In Polish.

The distribution of the current density is examined in a conductor of circular cross-section subjected to current surges of arbitrary shapes. Exact formulae are obtained for the electric and the magnetic field intensities in a transient state. (Science Abstracts).

225. Huber, J. C., Feasibility Study of the Wrap-Around (Solderless) Electrical Connectors. Missile Div., Chrysler Corp., Detroit, Mich., Tech. Memo. No. MT-M47J. AD-290 891 (25 Oct 57). 34pp.

The results of an investigation of the wrap-around (solderless) connections as compared to soldered connections is presented. Difficulty is sometimes encountered in soldering connections that can meet the standards required for missile electrical systems. It was thought that many of these problems could be eliminated if the wrap-around connection could be used in the missile electrical circuits, since this connection is solderless and reportedly more reliable than a soldered connection. Tests were designed to determine the best material from which terminals should be made, and further tests were conducted to compare wrapped connections to soldered connections. (ASTIA Technical Abstract Bulletin).

226. Hunt, L. B., "Electrical Contacts," Johnson Mathey and Co. Ltd., (May, 1946).

This book discusses primarily the engineering aspects of the contact problem. It does not go into the physical theory of the operation of contacts under various conditions, but does give a very excellent summary of most of the practical applications of contacts and what materials have been found suitable and are required for these various applicatrons.

The book is divided into three major parts. The first section discusses the design and selection of contacts under various electrical and mechanical operating conditions. Limited duty contacts, medium duty contacts, contactor contacts and circuit-breaker contacts are considered. In addition, the special proprietary contact alloys are also discussed. Electro deposited contact materials are included in this section. The third section discusses the main problems involved in contact engineering. Various shapes, methods of attaching, special types and contact sub-assemblies are considered. (ASTM Bibliography and Abstracts on Electrical Contacts).

227. Hurowitz, Mark, Reliability of Welded Electronic Connections. Electronic Defense Labs., Mountain View, Calif., Tech. Memo. No. EDL-M473. AD-278 350 (23 May 62). 17pp.

In four life tests, run to determine the reliability of welded electronic connections, measurements for joint resistivity and joint strength were made on each of several sets of samples. Respectively, the tests involved nickel ribbon welded to #24 buss wire, nickel strap to Kovar transistor welds, and nickel ribbon to 1/4 watt resistor leads (RC07GF). Some of these tests were in the open while others were run under 95 relative humidity for both cleaned and salted samples. A dc current was passed through the samples to accelerate joint failure. After a total of 6.9 x 10 to the 6th power weld hours of life test, no joint failures were recorded. Moreover, no gross joint deterioration occurred. (ASTIA Technical Abstract Bulletin).

228. Hutchings, E. E., "Methods for Improving Electrical Continuity of Joints in Screwed Steel Conduit Joints," Rep. Brit. Elect. Allied Industr. Res. Ass. Ref. F/T157 (1943). 8pp.

Certain general trends on the purely electrical aspect of the problem are summarized. Various protective coatings and jointing methods are examined. (Science Abstracts).

229. Hyde, N. E., "Resistance of Dry-Circuit Relay Contacts," Ingeniøren B. 71, 720-5 (Dec. 15, 1962). In Danish.

Deals with contact resistance testing of relays as low-level switchings, discussing firstly the conditions for carrying out and evaluation of contact resistance measurements of low-level circuits (dry circuits) and secondly the development of a continuously-monitoring contact resistance measuring equipment, designed for life tests. Finally, the results of low level tests on several types of hermetically sealed realys, involving more than 100 million contact resistance measurements, are discussed. Several sealed relays displayed increasing contact resistance during life tests, but a higher degree of reliability of low contact-resistance was

obtained in relays where the contacts were contained in a separate sealed compartment, divorced from the coil. (Science Abstracts).

230. Ittner, W. B. and Magill, P. J., "A Survey of Contact Resistance Theory for Nominally Clean Surfaces," I.B.M. J. Res. Developm. 1, 44-8 (Jan., 1957).

While the theory of electrical contact resistance is, for the most part, well known, it is difficult to apply directly to the prediction of experimental results since, in general, the theory involves microscopic parameters beyond the control of the investigator. Recent measurements of contact resistance as a function of the applied contact load, carried out under specified conditions, have yielded results which are in excellent agreement with the general theory. In contrast, however, to a number of previous publications, the results indicate that the contact area is determined completely by the applied load and an effective plastic yield pressure. Under conditions where contact wipe and vibration are held to a practical minimum, the contact area can be specified in terms of a plastic yielding mechanism down to pressures as low as 0.1 gram. In this region the bulk of the contact resistance is seen to be attributable, for nominally clean contacts, to an absorbed gaseous monolayer approximately two angstroms thick. (Science Abstracts).

231. Ivanchenko, O. I., "Bolted Busbar Connections," Elekt. Stantsii, 58-62 (Aug., 1961). In Russian.

When dealing with bolted connections in Al busbars, it is necessary to take account of the loosening effect due both to creep in the metal and plastic deformation of the bolts. The stability of such connections can be improved by the use of special spring washers. Hot tinning is one way of ensuring good contact, providing protection against corrosion comparable with copper-plating. Greasing of the contact surfaces is also stated to be desirable. 6 refs. (Science Abstracts).

232. Janz, G. J. and McIntyre, J. D. E., "A Precision Conductance Bridge of New Design," J. Electrochem. Soc. 108, 272-6 (March, 1961).

A conductance bridge in which the essential component is a precision impedance comparator and which combines speed, wide range, and accuracy in measurements is described. (Science Abstracts).

233. Johnson, Robert E., Electrical Resistance Corrosion Indicators Literature Report. Rock Island Arsenal Lab., Ill., Technical Rept. No. 62-1694. AD-282 937 (11 May 62). 14pp.

Research was reviewed to establish the degree of sensitivity of electrical resistance corrosion indicators and their applicability to the evaluation of corrosion-preventive oils and compounds. Laboratory work conducted under carefully controlled conditions indicated a high degree of sensitivity utilizing thin film indicators. Exposed specimens which exhibited no corrosion when examined visually provided small resistance changes of 1% to 5% by careful electrical measurements during the same period. Although each individual electrical indicator detected corrosion, variation in response or lack of reproducibility indicated an undesirable factor for use in field tests. The adaptation of probe type specimens, to a glass slide having a thin metal film, provided a high degree of sensitivity. Satisfactory results could be obtained only after a thorough check of the electronic system and elimination of variables in the procedure. (ASTIA Technical Abstract Bulletin).

234. Jones, F. Llewellyn, "The Physics of Electrical Contacts," Oxford: Clarendon Press (1957), 219pp.

Because of their wide application electrical contacts are broadly classified here as those used in: (i) power circuits; (ii) communication circuits; and (iii) circuits where the current and voltage are small. Problems in (i) are mainly those of electrical discharges; those in (ii) depend on the properties of metals at very high temperatures; in (iii) they involve the properties of surface tarnish films. The nine chapters are: Introduction, which outlines the problems encountered; Fundamental Concepts; Early Work on Contact Bridges, which analyzes work done before 1945; Mechanism of Fine Transfer, which gives the mathematical theory of the bridge; Stability and Shapes of Molten-metal Bridges, which describes recent experimental work; Properties of Metals at high temperatures, which explains how the theory of contact physics is applied to the study of electrical, thermal and thermoelectrical properties of metals at temperatures up to their boiling; Erosion and Transfer, which describes recent observations of erosion craters and discusses quantitative data obtained using radiotracer techniques; Discharge Phenomena at Contacts, which discusses initiation, maintenance and extinction of discharges, precontact as well as at break; and Surface Film Phenomena, which describes the influence of tarnish films and deals with the carbon brush. Wherever possible rigorous mathematical analysis is given. (Science Abstracts).

235. Jones, F. Llewellyn, "The Physics of Electrical Contact Phenomena," Brit. J. Appl. Phys. 12, 318-322 (July, 1961).

An outline is given of the nature of the fundamental physics processes occurring at an electrical contact and the problems to which they give

rise, particularly in relation to light duty electrical contacts. The discussion includes contacts in which currents and potentials are of the order of amperes and volts, and also the so-called electrostatic contacts, in which one or other or both of these quantities may be extremely small. Recent work on microscopic molten metal bridges; micro-arcs (both of which are important in metal transfer) and the problems of "electrostatic" contacts which mainly depend on surface properties, are described. Outstanding problems are discussed and the method by which they are being attacked are indicated. (Science Abstracts).

236. Jones, F. Llewellyn, "Measurement of Metal Transfer in Electrical Contacts by the Radioactive Isotope Method," Brit. J. Appl. Phys. 12, 485-489 (Sept., 1961).

The use of radioactive isotopes in the measurement of the transfer of metal from one electrode of an electrical contact to the other is described and details of the experimental procedure are given. The relation between matter transfer and circuit inductance at very low values of the inductance was determined for platinum and palladium contacts operating at potential differences of the order of one volt. It is shown that for these metals there is no range of inductance down to 10^{-8} H over which the transfer is independent of inductance. The amount of transfer in relation to the volume of the molten metal bridge between the electrodes is considered, and the significance of the results in the light of theories of the phenomenon of transfer is discussed. (Science Abstracts).

237. Jones, T. I., "Capacitors, Inductors and Resistors at Radio Frequencies," Notes Appl. Sci. Nat. Phys. Lab. 22, (1961). 23pp.

Six short papers give helpful comments on: (1) Impedance measurements using resonant lines; (2) Impedance measurements using the dielectric test set; (3) Other resonance methods; (4) Measurement of very small capacitances; (5) Impedance measurements with NPL radio-frequency Schering bridge; (6) Refinements in the use of the BBC type multi-ratio admittance bridge. (Science Abstracts).

238. Jurich, S., A Comparative Study of the Electrical Contact Properties of Titanium. Wright Air Development Center, WADC-TR-52-289. AD-2178 (Feb., 1952). 74pp.

Electrical contact properties of commercially pure titanium have been compared to those of Cu, Al, and steel. To determine the relative effect of heat and moisture on Ti when used with dissimilar metals, a comparative study of Ti, Cu, Al, and steel was undertaken. Various assemblies of bolts, washers, nuts, terminals, and rivet-terminal combinations were mounted on a panel of each of the metals and were then subjected to high humidity for a three-month period. Suitable terminal combination for each type of metal were found. More contact assemblies proved unsuitable when used on titanium than when used on the other metals which were tested. Results indicated that care should be exercised in the selection of combinations of metals to be used to electrically connect wire to titanium chassis or panels. In most cases, initial resistance values of titanium were higher than those of other metals which were tested, but the difference in resistance value of titanium decreased materially as the test proceeded. (ASTIA Technical Abstract Bulletin).

239. Kaden, H., "The Behaviour of Cables of Variable Characteristic Impedance When Subjected to Television and Test Pulses," Arch. Elekt. Übertragung 7, 157-62 (March); 191-8 (April, 1953). In German.

Coaxial wide-band cables suffer invariably from slight changes in characteristic impedance due to dimensional tolerances, which cause "blurring" of transient response. The experimental technique employed is to send pulses or suddenly interrupted a.c. signals and to observe the decaying blur similar to overshoot. This is caused by two effects: (1) double internal reflections and (2) the combination of single internal reflections and cable terminal reflections. The first effect is proportional to the product of the characteristic impedance fluctuations and its second derivative and decreases linearly with time in short and in exponentially long cables. The second effect depends mainly on the first derivative, the decrease is proportional to $\Delta t^{-1/2}$ in short cables and exponential in long cables. Experimental techniques are described which provide a visual display on a c.r.o. of the impedance fluctuations and reflection phenomena. A series of pulses of alternating polarity are applied as a test signal, a square-law detector measuring the fluctuating output and also the derivatives, which yield the "correlation factor" determining the amount of blur or overshoot. The measuring apparatus is indicated briefly and described by means of block diagrams; it consists essentially of a pulse generator coupled via a differential transformer to a bridge comparing the cable under test with a known impedance. Calculated and experimental results are compared and the relationship between the derived correlation function and the reflection losses and energy spectrum is analysed and discussed. (Science Abstracts).

240. Kaganov, M. A., "The Application of the Thermoelectric Method of Measuring Temperature Differences in Electrical Conductors," Pribory i Tekh. Eksper., 145 (Jan.-Feb., 1958). In Russian.

Describes a simple scheme for direct measurement of small temperature differences in electrical conductors using two thermocouples and a bridge circuit. The circuit avoids the necessity for insulating one of the thermocouple working junctions, which is a potential source of error on the usual method where a differential thermocuples is used. (Science Abstracts).

241. Kaganov, M. I. and Azbel', M. Ya., "Towards the Theory of the Anomalous Skin Effect," Dokl. Akad. Nauk SSSR 102, 49-51 (1956). In Russian.

Recently a large number of papers have appeared discussing the dependence of the surface impedance $Z = (4\pi/c)(E/H)_0$ of metals on the mean free path of the conduction electrons. Sondheimer introduced anisotropy of the metal by using anisotropic effective masses and obtained explicit expressions for the limiting case where the effective mean free path is considered infinite and the current considered due to electrons moving parallel to the surface of the metal. Pippard obtained an expression for Z valid for an arbitrary dispersion law for the electrons. In this paper an exact expression is found, for an arbitrary dispersion law, for the limit of an infinitely large mean free path. It is shown that: (1) The dependence of the impedance on the angle between the surface normal and the crystal axes is determined by a tensor. (2) The impedance varies with frequency as $\omega^{2/3}$ and the relation between ReZ and ImZ does not

depend on the dispersion law. (3) The expressions for Z do not contain quantities depending on collisions with the lattice which permits their use for the determination of the shape of the Fermi surface. (Science Abstracts).

242. Kallir, L. and Hutchings, E. E., "Electrical Continuity of Steel Conduit Joints," Rep. Brit. Elect. Allied Industr. Res. Ass. Ref. F/T152a, (1943). 11pp.

Describes an investigation on screwed- and gripped-type steel-conduit joints to determine under what conditions higher resistances may occur. Tests were made to study the effects of exposure to abnormal humidity, contact with wet concrete and mechanical stresses. Measurements were made on existing installations in buildings. (Science Abstracts).

243. Kappler, E., "Variation of Contact Resistance with Contact Pressure," Z. Angew. Phys. 2, 313-319 (August 15, 1960). In German.

Effects of various factors on the above variation for "crossed-wire" contacts of precious metals and their alloys were investigated. These included effects of applied load resulting in plastic deformation, of monomolecular and thicker foreign films, of surface condition, elastic after-effect and hysteresis. The review includes diagrams, graphs, tables, and photomicrographs. (Battelle Library Review).

244. Kappler, E., Ruchardt, E. and Schlafer, R., "Contact Resistance as a Function of the Contact Load," Z. Angew. Phys. 2, 313-319 (August, 1950). In German.

The contact resistance between crossed cylindrical wires was measured by a voltmeter and ammeter method for Ag, Au, Pt, AgPt 70/30, AgPt 90/10, and Ni. The load was applied by an electromagnet with the aid of a machine which permitted the load to be weighed. The theory of the ideal case leads to a variation of resistance with $P^{-1/3}$ for the elastic, and with $P^{-1/2}$ for the plastic region. Departures from the theory are caused by imperfections of the surface and the adsorbed layer, which adds a resistance proportional to the contact area. The effect of several cleaning and polishing methods was investigated. The results obtained with intermittent but regularly increasing load agree well with the theory until the plastic deformation is so great that the approximation (contact radius $\ll$ wire radius) breaks down. Subsequent measurements with falling load show hysteresis which depends on the surface finish; welding sometimes occurs. An oil film protects the surface. (Science Abstracts).

245. Karandeev, R. B., Mizyuk, L. Y. and Shtamberger, G. A., "Self-Balancing Bridge for Independent Measurement and Recording of the Resistive and Reactive Components of an Impedance," Priborostroenie, 15-17 (June, 1960).

The automatic balancing of an impedance measuring bridge is very complex if indeed it has been achieved. However, considerable simplification is possible by obtaining a separate balance for the resistive and reactive components of the impedance. This method know as quasi or semi-balancing is described as applied to an automatic recorder. The bridge network is

of the type employing two resistive and one capacitive arm, the fourth arm containing the unknown impedance Z in series with a fixed resistor R_2 joined together at point m. Z and R_2 are shunted by a much lower resistor having a slider 'e'. The a.c. input to the bridge is fed as usual to two opposite corners. Across the other two corners, corresponding to the usual detector, is connected a high value non-inductive resistor having a slider 'f'. Points e and m are connected to the input of a phase-sensitive detector which measures the resistive component and points f and m are connected to another phase-sensitive detector which measures the reactive component. The condition for quasi-balance of the resistive component is that the voltages at points e and m should be in quadrature. Likewise points f and m for the reactive component. Balance is obtained by adjusting sliders e and f until the outputs of the respective phase-sensitive detectors are zero. The outputs of the detectors are fed to the reversing windings of two electric motors whose shafts are rigidly coupled to the sliders e and f on the balancing resistors. Thus if an arm is unbalanced the motor moves the slider until the phase difference is again 90° when the phase-detector output falls to zero and the motor stops. The motor spindle may also have a recording pen fixed to it so that the arc over which it moves is a measure of the resistive or reactive magnitude. The mathematics of the bridge with vector and circuit diagrams and 10 references are given. (Science Abstracts).

246. Karbowiak, A. E., "An Instrument for the Measurement of Surface Impedance at Microwave Frequencies," Proc. Instn. Elect. Engrs. 105B, 195-203 (March, 1958).

A theory is given of an instrument for the measurement of surface impedance at microwave frequencies. Two prototype instruments--one for 6 Gc/s and one for 34 Gc/s--are described, and the measurement procedure is explained. Basically the surface impedance ($Z_s = R_s + jX_s$) is deduced from the resonant conditions of the cavity operated simultaneously in H_{01} - and E_{11} - modes. In particular, the cavity bandwidth is a measure of the surface resistance R_s, and the surface reactance, X_s, is deducible from the separation between the H_{01} and E_{11} responses. As an illustration of the use of the instruments a number of experimental results are cited. (Science Abstracts).

247. Karo, D., "The Measurement of Voltage, Current, Power, and Impedance at High Frequencies. A Novel Differential Reflecting Electrometer," Beama J. 62, 33-5 (Nov., 1954).

A double-vane electrometer is described in which the two fixed pairs of plates are not connected together, but one pair is fed from a known voltage and the other from the test voltage. The moving system is adjusted to balance, forming a null differential method of low capacitance suitable for h.f. measurements. Differing mechanical constructions are shown, and there is also a triple form. Detailed analyses and methods of working are given, with comparative test results. (Science Abstracts).

248. Karo, D., "Measurement of Impedance in the Audio-Frequency Range," Engineer 208, 687-90 (Nov. 27, 1959).

Mainly because of the effect of residuals in the standard resistors, the number of bridge circuits that are really precision methods of measuring impedance is very limited. This article describes a novel bridge circuit in which the number of resistance standards is reduced to the barest minimum and the effect of the remaining residuals is eliminated by a double balance. One standard resistance is used for the setting of the bridge, and this is the only one in the circuit which would have a small residual. (Science Abstracts).

249. Karo, D., "A Modified Wide-Range Shunted-T Circuit for the Measurement of Impedance in the a.f., r.f. and v.h.f. Ranges," Proc. Instn. Elect. Engrs. III 100, 25-8 (Jan., 1953).

Describes a shunted-T circuit provided with a voltage divider, consisting of two resistors or two capacitors, at the input, connected in series across the source. The shunt is connected across the source, whilst the T-circuit is connected across the lower voltage part of the voltage divider. In this manner the voltages of the shunt and the T-circuit are made different, although they are provided by the same source. The balance condition depends, therefore, not only upon the values of the impedances in the circuit, but also upon the values of the components of the voltage divider. The circuit therefore has a multiplying ratio, or ratio arms, and thus has a much wider range of measurement for a given set of standards. Furthermore, by means of measurement with an additional standard in the circuit, the angular frequency can be made to disappear from the balance equations. Tests have been made over a wide range of resistance, inductance and capacitance, with frequencies varying between 1000 c/s and 50 Mc/s. The accuracy varied between $\pm$0.020% and about $\pm$1%, depending upon the frequency and the standards used. (Science Abstracts).

250. Karo, D., "A Novel, High-Accuracy Circuit for the Measurement of Impedance in the A.F., R.F., and V.H.F. Ranges," Proc. Instn. Elect. Engrs. 105B, 505-10 (Nov., 1958).

The paper describes a high-accuracy measuring circuit suitable for frequencies from 50 c/s to v.h.f. There are two branches in the circuit, one of which contains the unknown impedance. The two branches are fed in phase opposition from the secondaries of two mutual inductors or two transformers. Due to the feeding in opposition of the two branches, the transfer impedances are very simple, no negative real terms are present and no more than two variable standards are required for balance. The balance equations in the majority of cases do not contain the term ω (angular frequency), the frequency need not therefore be known very accurately and the calculations are simple. Furthermore, at balance, the detector, source and all the circuit components except one have one terminal connected to earth. The potentials are therefore fixed and most of the capacitances to earth are eliminated; those that remain shunt one secondary and the standard in one branch of the circuit and can easily be determined or otherwise taken into account in the calculations. Tests have been made over a wide range of resistance, inductance and capacitance between 100 c/s and 50 Mc/s. The error varied, according to the standards and the frequency used between $\pm$0.001% and $\pm$0.01%. (Science Abstracts).

251. Kaufman, J. W., Sutton, H. R., Balchaitis, A. V. and Matthias, W. R., "Dry-Circuit Evaluation of Mechanical Connections," Elect. Manufng. 25, 116-21 (April, 1960).

A summary of the causes of non-conduction in low-level electrical contacts and the results of environmental tests on two forms of mechanical-type connectors evaluated from a reliability standpoint in dry circuits encountered in defense electronic equipment. (Science Abstracts).

252. Keil, A., "Materials for Electrical Contacts," Springer-Verlag, (1960). 347pp. In German.

This book discusses contact phenomena primarily from the standpoint of the materials which have become useful in practical areas. These are discussed from the standpoint of physical and chemical effects which take place during switching and include the mechanism of contact welding, the technology of contact materials, and material choice in practical applications. The book is well organized and should be in the library of anyone who is concerned with contact problems. (ASTM Bibliography and Abstracts on Electrical Contacts).

253. Keil, A. and Meyer, C. L., "Silver as Working Material in Electrical Engineering," Schweiz. Arch. Angew. Wiss. Tech. 21, 264-70 (Aug., 1955). In German.

The physical and chemical properties of pure Ag and of Ag alloys are discussed with respect to use for electrical contacts (interrupters). Examples are given of alloys, and of fritted metals with Ag as a basis, which resist sulphur attack and also reduce surface wear of contacts in the electric arc. Methods are described for the protection of non-precious metals by electrolytic Ag, and for surface metallization of insulating materials with Ag. Finally, soldering problems with Ag alloys are considered. A postscript states that Ag-Mn alloys containing some Sn are useful for resistances, and that Ag-Pd alloys are suitable for potentiometer wire. For the most efficient fine contacts, however, Au and its alloys must be used. (Science Abstracts).

254. Kempf, R. A., "Coaxial Impedance Standards," Bell. Syst. Tech. J. 30, 689-705 (July, 1951).

Bridge networks used in development tests on coaxial cable are calibrated by comparison with impedance standards consisting of a group of short-length precision coaxial lines. Precise formulae relate the distributed primary constants of the standard lines with their dimensions, the constants of the conductors and the expanded polystyrene insulation. The design and construction of a group of standards which provide a range of values over a broad band of frequencies is discussed and illustrated by diagrams and graphs. (Science Abstracts).

255. Kemnitz, W., "Investigation of the Absolute Determination of Electrical Resistance Using the Tuttle Bridged-T Circuit," Elektrotech. u. Maschinenbau 79, 305-10 (June 1, 1962). In German.

The experimental arrangement and the method of measurement in terms of a standard inductance are described. The required magnitudes of components are given for measurements at frequencies between 100 c/s and

1000 c/s. An equivalent circuit detailing all strays, is analysed to determine the sources of error, and to derive correction factors. Experimental results establish the ranges of usefulness of these factors. (Science Abstracts).

256. Killian, S. C., "Aluminum Busbar Laps and Joints Need Not be Larger than Copper," Elect. World 128, 118-119 (Sept., 13, 1947).

The commonly accepted theory that Al must have larger laps and joints in busbars than Cu is disproved by the results of laboratory heat-runs. With Al, care is required in making the joint, and the best results are obtained if a protective compound is used. In one case this is a greasy substances (No-ox-id) which is spread on the joint and then wire-brushed or scraped; another substance (Alcoa) can be painted on the joint before bolting. Data on the temperature rise of Cu-Cu, Al-Al and Cu-Al, joints and values of contact potentials, which have a bearing on corrosion hazards, are tabulated. (Science Abstracts).

257. King, V. J., "Liquid Alloy for Making Contacts to Metallic and Nonmetallic Surfaces," Rev. Sci. Instrum. 32, 1407 (Dec., 1961).

Mercury-indium alloys containing thallium exhibit unusual wetting tendencies that make them particularly useful in achieving liquid and solid contacts to metallic or nonmetallic materials, including refractories, semiconductors, glass, and plastics. (Science Abstracts).

258. Kinyon, A. L., "Earth Resistivity for Grounding Grids," Trans. Amer. Inst. Elect. Engrs. III 80, 795-800 (1961).

Resistivity values measured near ground surfaces vary widely with changes of moisture content and temperature but become more consistent as the depth is increased. For separations of probes of 20 to 30 ft seasonal variations are measurable, but become negligible when the separations exceed 100 ft. For substation earthing tests using four probes, separations of 100 or 200 ft should be used and the earth resistivity taken from among the lower measurements obtained from a comprehensive survey. (Science Abstracts).

259. Kirkscether, E. J., "Ground Constant Measurements Using a Section of Balanced Two-Wire Transmission Line," Trans. Antennas and Propagation AP-8, 307-12 (May, 1960).

When an open-circuited section of unshielded balanced two-wire transmission line is introduced perpendicularly into earth (or some sample under test), the electrical characteristics of the latter may be found by simple input-impedance measurements. By laboratory sample measurements the classical short- and open-circuited method can be used. Some exact and approximate procedures are presented and their utility and practical limitations discussed. Some precautions as to how possible errors and inexactnesses in the measurements and following calculations may be avoided are given. As an example, a typical earth sample is tested in a frequency range from 0.6 to 400 Mc/s, with graphical representation of the most important electrical constants: conductivity, dielectric constant, attenuation, velocity of propagation, etc., which exhibit great variations in the frequency range cited. The measurement

method presented seems to be adequate to use in small mobile equipment, with which the ground in general can be tested in its original site and under natural conditions without the necessity of being removed. (Science Abstracts).

260. Klaudy, P., "Properties and Possible Applications of Liquid Contacts," Elektrotech. Z. 76, 525-32 (Aug. 1, 1955). In German.

The contact resistance of Mo, W, Cr and steel contacts with Hg as contact liquid was measured and found to be independent of pressure (0-300 atm) and current (0.05-1,100A). The absolute value of liquid contact resistance is very much smaller than that of solid contacts. Current passes throughout the contact area through the surface film. When the latter is removed, no surface film forms under Hg for quite a long time and the contact resistance remains small even if air or gases are dissolved in the Hg, provided that they do not touch the contact surface. When the contacts are not protected by Hg, high-resistivity surface films are formed consisting of air or gas molecules. Application for sliding contacts in machines is considered. (Science Abstracts).

261. Klaudy, P., "Current Collection at High Speeds," Maschinenbau u. Wärmewirtsch 11, 315-327 (Oct.-Nov., 1956). In German.

Given a sufficient contact area and suitable pressure, stationary metal-to-metal contacts may carry very heavy currents. Sliding and moving contacts have a limited current-carrying capacity and in difficult cases an interposition of a fluid medium between the solid metallic surfaces is indicated. The physical process of the current through the contacts is analysed; three reasons for the flow of current despite the formation of non-conducting layers on the contact surfaces are explained. A thorough laboratory investigation of fluid contacts was made and their electrical and mechanical characteristics are described. Recommendations are given for designing fluid contacts suitable for collection at high speeds. (Science Abstracts).

262. Kleis, J. D., "Electrical Contact Materials," Electrical Manufacturing 55, 102-107 (April, 1955).

The author discusses properties of metals, alloys and compounds which are used as contact materials. Electrical and mechanical properties and the limitations of the various materials in contact applications are described.

263. Klockhaus, W., "A Simple Instrument for Measuring Impedance Deviations and Matching Errors in the Frequency Band of 0.3 to 300 Mc/s," F & G Rdsch. 37, 218-23 (Oct., 1953). In German.

The instrument described is an r.f. bridge of ingenious design, all its arms being connected by and partly consisting of coaxial tubes, the reference and measuring variable resistors being also of special coaxial design. The critical part of the equipment is enclosed in a probe, 12 x 8 x 6 cm in size, which can be brought near the cable, line, feeder, or aerial under investigation, the remaining stationary part containing

power supply, 1 V source for the bridge and indicator being connected by a cable. The equipment is illustrated by a block diagram and photographs; typical measurements are described and compared with theoretically obtained values and shown in several curves. (Science Abstracts).

264. Klund, K., "Inexpensive High Resolution Wheatstone Bridge," Rev. Sci. Instrum. 31, 1004 (Sept., 1960).

A modified circuit of the Wheatstone bridge by which extremely small changes of resistance can be measured. (Science Abstracts).

265. Knowles, E. G., "Electrical Contacts," Elec. Mfr. 1, 8-10 (1957).

The author considers only medium-duty contacts, and tabulates the physical properties of silver and silver alloys most often used. Silver-graphite is preferred to silver-nickel or silver as regards contact resistance, and is recommended for use in cases where the design of the switch eliminates the more disruptive effects of arcing. (ASTM Bibliography and Abstracts on Electrical Contacts).

266. Kochan, V. A., "The Accuracy of Resistance Measurements With a Double Bridge," Elektrichestvo, 65-8 (1953). In Russian.

It is generally assumed that even in very precise resistance measurements using a double bridge the effect of an additional term d in the equilibrium condition is negligible. However, a careful analysis shows, first of all, that the two forms of equilibrium conditions generally used are unsuitable for a correct error estimation, so that the above statement in general lacks foundation, even though it is always supplemented by the stipulation $R_4R_3' - R_4'R_3 = 0$, or $\Delta R_4|R_4 - \Delta R_3|R_3 = 0$, and the condition that r should be as small as possible. The latter condition is frequently impossible to fulfil, the more so as verifications of potentiometers, bridges and resistance boxes often require $r = R_x$; in the case of heavy-current shunts even $r = 10R_x$ may be required. By converting the conventional relations to a form more suitable for error estimation, and carefully considering every possible source of error, the author proves that it is theoretically and practically possible to select the resistances and their ratios in such a way that d has practically no influence at all on the measuring results. Two numerical examples given show clearly that double-bridge measurements may be made as reliable and precise as compensation methods. (Science Abstracts).

267. Kohane, T., "The Measurement of Microwave Resistivity by Eddy Current Loss in Small Spheres," IRE Trans. Instrum. 1-9, 184-6 (Sept., 1960).

The sample to be measured, which is in the form of a small sphere, is introduced into a resonant cavity at a point of maximum magnetic field. The resistivity of the sample is determined from the measurement of the change in the cavity Q-factor resulting from the insertion of the sample. The method is particularly suitable for measurement of samples of low resistivity and an application to measurement on some ferrites is indicated. The experimental precedure and method of evaluation of sample resistivity are discussed. (Science Abstracts).

268. Kohler, K., "The Measurement of Small Reflection Coefficients at High Frequencies," Frequenz 15, 12-17 (Jan., 1961). In German.

Measurement accuracy of 0.1% is possible at 4 Gc/s using commercially available directional couplers and ancillary components with suitable technique. Amplitude and phase calibrations are effected by respectively replacing the test-piece with a short-circuit termination and comparative measurements with adjustment of a four stub tuner. The theoretical analysis includes a discussion of sources of error. (Science Abstracts).

269. Kouwenhoven, W. B. and Little, C. W., "Contact Resistance" Welding Journal 31, 457s-465s (October, 1952).

Deals with laws that apply to resistance offered by electric contacts used in resistance welding and in electric circuits. Metals used in investigation were Al, brass, Ag, and stainless. Photomicrographs, diagrams, and graphs. (Battelle Technical Review).

270. Kouwenhoven, W. B. and Sackett, W. T., Jr., "Contact Resistance--The Contribution of Non-Uniform Current Flow," Elec. Engg. 71, 264-268 (Mar., 1952); Trans. AIEE 70, 791-795 (1951).

Results of the study provide an explanation of spreading resistance, and curves are presented for calculating its magnitude for single and multiple constricting contacts. (Battelle Technical Review).

271. Kouwenhoven, W. B. and Tampico, J., "Measurement of Contact Resistance," Weld. J. 19, 408s-413s (1940).

272. Kragelsky, I. V. and Demkin, N. B., "Contact Area of Rough Surfaces," Wear 3, 170-187 (1960).

Gives analysis of the contacting process of surfaces that are rough and wavy; uses three contact areas: apparent, contour and real. A unit protrusion is modeled as a cone with a spherical top deformed elastically and plastically. It is assumed that elastic deformation of the spherical protrusion top takes place first; this is then flattened, allowing plastic deformation of the truncated cone. On the basis of this model, a formula is deduced to calculate real contact area as a function of load, geometry of the surface, and properties of the material. (Battelle Technical Review).

which are deformed elastically. On the basis of this model a formula has been deduced to calculate real contact area as a function of load, geometry of the surface, and properties of the material. (Wear).

273. Kraus, A., "Reflection Coefficient Curves of Compensated Discontinuities on Coaxial Lines and the Determination of the Optimum Dimensions," J. Brit. Instn. Radio Engrs. 20, 137-52 (Feb., 1960).

Discontinuities on coaxial lines are caused either by irregular cross-section or variation of dielectric constant. Equivalent circuits of different types of discontinuity are given. The node-shift technique employing an adjustable short circuit for determining the reflection coefficient is described. Test results are discussed at length and a series of curves for various configurations given. (Science Abstracts).

274. Kroebel, W., "Methods of Fault-Location and Inhomogeneity Measurements on Cables by Use of the Echo-Sounding Principle," Z. Angew. Phys. 5, 48-52 (1953). In German.

An explanation is given of the principles of the pulse-echo method as applied to cable testing, together with an outline description of suitable equipment for generating the pulses required and for evaluating the time delays of the echoes. (Science Abstracts).

275. Krugel, L., "A Quantitative Method of Determining Irregularities in Wideband Cables by the Use of Pulses," Fernmeldetech. Z. 7, 3-9 (Jan., 1954). In German.

Describes the pulse technique for measuring the position and magnitude of cable irregularities. An extensive list of references is given. (Science Abstracts).

276. Kuhn, H. D. and Rieder, W., "The Effect of Natural Films on Contact Resistance and Contact Welding," Elektrotech. u. Maschinenbau 79, 493-9 (Oct. 1, 1962). In German.

The first results of an extensive test programme on the effects of pollution on contacts are given in tables and curves. The popular belief that films on contacts have a beneficial effect on welding characteristics is not substantiated, but it is emphasized that the results so far cover only a narrow range of conditions. (Science Abstracts).

277. Künzler, H. and Bohren, H., "Investigations of Fine-Soldered Unions," Tech. Mitt. PTT 32, 329-51 (1954). In German.

The chemical and physico-chemical problems which arise at soft-soldered junctions are stated and investigated. Comprehensive experiments are described whose objective is the preparation of a solder containing constituents which resist corrosion. The influence of temperature upon the structures of the soldered metals and upon the quality of the junctions is examined. Attention is given to the possibility of reducing the loss of copper when present in solder at elevated soldering temperatures, since copper promotes resistance to corrosion. 35 figures are given. (Science Abstracts).

278. Kurtze, G., "The Measurement of Mechanical and Acoustical Impedances," Tech. Mitt. PTT 34, 361-9 (1956). In German.

After tabulating the electrical analogues of mechanical variables, this review describes the most useful methods of impedance measurement. For mechanical measurements the direct-coupled electromechanical transducer is treated. For acoustical measurements standing-wave methods are analyzed. These fall into two categories; the air-filled steel tube, which is analogous to the electrical transmission line, and the liquid medium bounded by acoustically soft material, which is equivalent to the electrical waveguide. An appendix lists the various parameters connected with mechanical resonance, such as Q value, logarithmic decrement and loss tangent. (Science Abstracts).

279. Lafferty, R. E., "Measuring Return Loss Accurately," Electronic Industr. 19, 70-4 (Oct., 1960).

Two methods of measuring return loss are described. In the first method, essentially, a bridge is used to compare the unknown impedance with the characteristic impedance. The detector, which is a sensitive electronic voltmeter, measures the effective return loss directly in decibels if the bridge is adjusted, initially, with respect to the characteristic-impedance. An important part of the bridge arrangement is an unbalance-to-balance transformer used to feed the bridge from a suitable signal generator and the design aspects of such a transformer are briefly discussed. The equipment is capable of measuring the return loss down to -55dB and, depending on the type of circuit used, measurements in the range from 5 to 200 Mc/s are possible. In the second method described, use is made of a carefully constructed and adjusted coaxial directional coupler as a four-port device, in place of the bridge arrangement. The relative merits of the two methods are briefly discussed. (Science Abstracts).

280. Lamberts, K., "Measurement of Impedances in the High-Frequency Range With the Aid of Bridged and Parallel-Connected T-Sections," Arch. Tech. Messen. 189, T108-T109 (Oct., 1951). In German.

After mentioning the difficulties caused by stray capacitances in normal bridge methods of measurement at h.f. the author discusses the advantages of the bridged-T method. General conditions for balance are derived, using the star-delta transformation. Stray capacitances which would be troublesome in a bridge now appear across the generator or the null indicator and thus do not affect the balance. An analysis is given for two cases of inductance measurement, (a) when the unknown inductance is the bridging element, and (b) when it has one end earthed, in which case it is placed in parallel with the shunt element. This case is extended to include measurement of capacitance or inductance by a difference method. In order to eliminate the precision variable resistor needed in addition to a variable capacitor, the bridging element may be replaced by an unsymmetrical T-network of fixed capacitance and resistance and a variable capacitance. This network is connected in parallel with the main T-network, and balancing is now performed by adjustment of two variable capacitors only. (Science Abstracts).

281. Lampert, M. A. and Rose, A., "Transient Behavior of the Ohmic Contact," Phys. Rev. 113, 1236-1239 (March 1, 1959).

Under certain conditions the response time of a solid for current transients may be determined by the properties of the injecting contact rather than of the bulk. In this case, it is the time required for readjustment of the space-charge barrier at the contact for delivery of the new steady-state current. The critical parameter determining the response time of the contact is the total amount of excess charge within one Debye length of the potential minimum in the space-charge barrier. Trapped, as well as free, excess charge must be included in the calculation of the Debye length. The product of gain (G) and bandwidth ($1/\tau_o$) for a photoconductor whose response time is contact-controlled is derived and expressed in the "universal" form $G/\tau_o = M/\tau_r$, where τ_r is the dielectric relaxation time under operating conditions. (Science Abstracts).

282. Lander, J. J. and Germer, L. H., "The Bridge Erosion of Electrical Contacts," J. Appl. Phys. 19, 910-928 (Oct., 1948).

Bridge erosion is the transfer of metal from one electrode to the other which occurs when an electric current is broken in a purely resistive l.v. circuit. It is associated with the bridge of molten metal formed between the electrodes as they are pulled apart, and more specifically with the ultimate boiling of some of the metal of this bridge before the contact is finally broken. This paper is concerned with fundamental studies of this molten bridge and with empirical measurements of the transfer of metal. From known physical constants one calculates that, when the melting point is reached at a current I, the diameter of the area of contact of two electrodes ~1.5×10^{-5} I cm. for Ag, Cu, or Au, and ~7.5×10^{-5} I for Pt or Pd. When the max. temperature of the molten bridge reaches the boiling point the mean bridge diameters are ~4×10^{-5} I and 20×10^{-5} I, respectively. These calculations were checked experimentally. On breaking a contact, ~6×10^{-14} I $cm.^3$ of metal is transferred from the positive to the negative electrode. This represents about 100 per cent of the volume of the molten bridge for Ag, Cu, or Au, and about 0.5 per cent for Pt or Pd. The amount of transfer can be decreased, and even its direction reversed, by heating the negative electrode, and by other means. Temperature distributions in the neighborhood of a contact were calculated and a theory developed to account for the reversal of direction of transfer. (Science Abstract).

283. Lavagnine, B. and Alby, B., "The Differential Transformer in Resistance Measurements at High Frequencies," Alta Frequenza 28, 119-32 (April, 1959). In Italian.

A third secondary winding is used, suitably poled, so that a standard variable capacitance can be employed to obtained balance when measuring an inductive impedance. The balance conditions are given, the construction of suitable toroidal transformers is described, and the results of measurements on three types of (overhead) wire up to 200 kc/s are presented. (Science Abstracts).

284. Lebrun, A., "Some Techniques for the Measurement of Impedances at Metre and Decimetre Wavelengths and Their Utilization for the Study of the Dielectric Properties of Solid and Liquid Substances. Application to the Case of Some Normal Saturated Alcohols," Ann. Phys. 10, 16-70 (Jan.-Feb., 1955). In French.

A full account is given of the theory and of the relative advantages of several variants of parallel-wire and coaxial-line methods of measurements at 10^6 to 10^{10} c/s. Detailed numerical values of ε' and ε'' are given for the normal C_7, C_8, C_9 and C_{10} alcohols at 20°C. Two dispersion regions are found in each case with critical wavelengths ~300 cm and ~6 cm. (Science Abstracts).

285. Leslie, W. H. P., "Choosing Transformer Ratio-Arm Bridges," Proc. Instn. Elect. Engrs. 108B, 539-45 (Sept., 1961).

Recently published papers on transformer ratio-arm bridges have given a false impression of their operating principles. The allocation of

shunt and leakage inductance to each winding of a toroidal 2- or 3-winding transformer is first considered. This is then applied to the analysis of bridges for particular practical applications proposed by Lynch, Thompson, the present author and Karo. The balance conditions are compared, when experiencing shunt stray impedance, and it is shown that three of the bridges each have their most suitable applications. This does not seem likely for the last type. (Science Abstracts).

286. Lettowsky, F., "A Method of Calculating the High-Frequency Resistance of Cylindrical Conductors of General Cross-Section," Arch. Elektrotech. 41, 64-72 (1953). In German.

Skin-effect is considered as a boundary-value problem for the wave equation set up within the conductor. For the extreme case of high frequencies the essential integrand can be expressed as a semi-convergent series. A formula for h.f. resistance is developed and applied to a Lecher-wire system and to conductors of rectangular cross-section. (Science Abstracts).

287. Lewis, R. K. and Norton, J. T., Infrared Detection of Weld Defects. Advanced Metals Research Corp., Somerville, Mass., Interim technical rept. no. 1. AD-253 966 (31 Jan 61).

The electrical analog has been used to simulate the temperature distribution in plates containing various types of defect. The resulting temperature field patterns have been analyzed quantitatively to give, for selected points on the specimen, the temperature difference due to the presence of the defect. This information, together with a precise specification of the infrared microradiometer permits a calculation of the size of the minimum detectable defect. It is shown that the predicted performance of the radiometer proposed for the present investigation is such that cracks 0.1 cm long or holes 0.1 cm in diameter can be detected with certainty. (ASTIA Technical Abstract Bulletin).

288. Lewis, R. K. and Norton, J. T., Infrared Detection of Weld Defects. Advanced Metals Research Corp., Somerville, Mass., Final rept. AD-263 983 (31 June 61). 30pp.

In the first phase of the program an electrical analog was used to simulate the surface temperature distribution in plates containing various types of defects when the plate was subjected to a known temperature gradient. The resulting temperature field patterns were analyzed quantitatively to give temperature differences due to the presence of the defect. This information permits a calculation of the minimum size of detectable defects when the performance of the temperature sensing device is known. The second phase of the program involved designing, constructing, and testing a device employing infrared techniques for measuring very small temperature differences in the vicinity of room temperature. This device, a micro-radiometer, is capable of measuring temperature differences as low as 0.05 degrees at a temperature level of 50 C. Temperature differences were recorded on metal specimens which revealed the presence of artifically introduced defects. (ASTIA Technical Abstract Bulletin).

289. Linckh, H. E., "Investigation of Migration of Material at Electrical Contacts," Elektrotech. Zeitschr. 72, 79-83 (Feb. 1, 1951). In German.

The search for substitutes for noble metals of the Pt group in fine contacts is described. Tests showed the fundamental behavior of various metals and alloys in relation to the electrical stresses. The chief factor is the so-called arc limit: Above this limit there is a high loss of metal by burning and vaporization; below it transfer takes place only from anode to cathode. Some examples of detrimental point formation and more favorable shapes of surface are given. Au-Ni (5 per cent) and Au-Ag-Ni alloys have favorable properties. The transfer of metal is explained by the Thomson effect associated with the liquid metal bridge. Measurements of the transfer for a number of metals and photographs of contacts are presented. (Science Abstracts).

290. Lindberg, P. A., "Measurement of Contact Migration by Radioactive Methods," Tele 4, 365-374 (1960). In Swedish.

The use of radioactive silver as a tracer is described for studying the migration of material from anode to cathode with silver contacts. The method was used to determine which of three circuits with the same contact operation led to minimum material migration. The circuits were a short-circuited winding, a parallel-connected resistance-capacitance circuit and a parallel-connected rectifier circuit. A series of opening and closing tests was carried out over 24-hour and 10-day periods and the results were analyzed statistically, the amount of material transferred being given in 10^{-15} kg per operation. Least material migration took place with the rectifier circuit. Autoradiograms are shown of the cathode contacts and the method of estimating the material transfer is explained in detail. The great advantage of the method is the speed of obtaining results--days instead of a year with conventional methods--but it is very costly. (Science Abstracts).

291. Little, C. W., Jr. and Kouwenhoven, W. B., "The Spreading and Interface Resistances of Electric Contacts," Trans AIEE 72, 314-23 (Nov., 1953).

Describes an investigation to determine, more precisely, contact resistance which in magnitude and location is of importance in resistance welding. Tests were limited to d.c. contact resistance of single-metal contacts between the butt ends of cylindrical contacts 1/2 in. dia. under static mechanical axial loads. The metals used were silver, aluminium, and a bronze, a brass, and a stainless steel alloy. The theoretical background is outlined with definitions for spreading and interface resistance, and the experimental procedure is described followed by tables of results obtained. Use of controlled variable contact patterns enables the above component resistances to be separated and some deductions are given. (Science Abstracts).

292. Lorrin, J., "Testing at Very High Frequencies of Production Lengths of Coaxial Lines," Câbles et Transm. 7, 218-241 (July, 1953). In French.

The effects of irregularities in a transmission line are expressed by introducing two extra coefficients into the line equations. For a given sample, these coefficients can be evaluated by measurement of the

input and transfer impedances of the production length. A null method of determining these impedances is described. The bridge balance is obtained by varying one arm and the test frequency. The designs of bridges for frequencies of 1-20 and 200 Mc/s are described. The superheterodyne receiver is kept in tune with the variable frequency oscillator by mixing the oscillator output with a second oscillator tuned to the i.f. and feeding the difference frequency to the receiver as its "local oscillator" signal. Experimental results are quoted. (Science Abstracts).

293. Lyst, J. O. and Babilon, C. F., "Detecting Fatigue Cracks in Notched Fatigue Specimens by Changes in Electrical Resistance," Materials Res. Stand. 2, 485-9 (June, 1962).

Describes a method of detecting cracks in a fatigue specimen by measuring the changes in the electrical resistance of the surface by direct-current conduction. Both resistance and crack-length were observed to increase as fatigue life was consumed. In rotating-beam fatigue tests, cracks propagated slowly until the crack covered about 5% of the cross-sectional area, after which the rate of propagation increased rapidly to failure. Fatigue cracks as small as 0.005 in deep could be detected in 0.330 in diameter specimens by this method, and cracks could be detected when the change in resistance was as small as 2.5%. (Science Abstracts).

294. Machk, H., "Contacts in Electrical Measuring Technique," Arch. Tech. Messen. 166. TI02-4 (Nov., 1949). In German.

A review of the most important contact properties and their relation to physical and chemical contact structure, with special reference to errors of measurement which may arise from faulty contacts. The main characteristics of Ag, Pt, Au, W, Al, various alloys, and graphite as contact materials are briefly discussed and tables of constants for a wider range of substances are given. (Science Abstracts).

295. Maddock, A. J., Fielding, C. C., Batchelor, J. H. and Jiggins, A. H., "The Effects of Dust and Force Upon Certain Very Light Electrical Contacts," Brit. J. Appl. Phys. 8, 471-6 (Dec., 1957).

A study has been made of electrical contacts of platinum--gold--silver and of gold when operated at contact loadings of the order of milligrams. The general random nature of failures to make contact is demonstrated and two major causes are considered as contributing to these, dust and surface films. This paper is concerned firstly with the effects of dust and a relation between dust concentration and number of failures has been established: it appears that dust is more likely to be troublesome at very low contact loadings. The second part deals with the effects of contact force, for the practical case of relatively uncleaned contacts, from 0--4000 μg. The work here described extends to lower contact loadings than has hitherto been reported: resistances values rise very rapidly at loads below 1 mg. (Science Abstracts).

296. Maguire, J. J., Determination of Flaw Geometry by Ultrasonic Pulse Contour and Spectrum Analysis. Watertown Arsenal Labs., Mass., Technical rept. 830, 5/2. AD-262 202 (July, 1961). 14pp.

The report describes the application of ultrasonic pulses of almost rectangular envelope to pulse-echo testing, resulting in the simultaneous transmission of a wide band of ultrasonic frequencies. In comparison to the essentially monochromatic ultrasound used in conventional test systems, this method permits the derivation of additional information from the test, obtained in the form of the spectral energy distribution after reflection from the defect. Besides determining the location of a flaw, it is now possible to gather data representing the flaw geometry. (ASTIA Technical Abstract Bulletin).

297. Mancianti, M., "Bridge for Measuring the Differential Resistance of Non-Linear Elements," Alta Frequenza 25, 15-31 (Feb., 1956). In Italian.

The non-linear resistance is connected as one arm of a resistance bridge. An alternating voltage is applied to two terminals of the bridge. A c.r.o. is used to compare the unbalance voltage with the applied voltage. (Science Abstracts).

298. March, F. C., "Solderless Grounding for Braided Shields," Electronic Equipm. Engng. 6, 48-50 (June, 1958).

Tests are reported on solderless techniques for grounding and splicing shielded and coaxial cables.

299. Marenesi, R., Paolucci, A. and Galeazzi, A., "Measurement of Tower Footing Resistance on Transmission Lines Fitted with Earth Wires," Energia Elett. 30, 236 (1953).

Impulses from a recurrent surge oscillograph are applied to the tower footing resistance and to a variable non-inductive resistor and the current waves are compared. Such comparisons is valid only for the time preceding the arrival of waves reflected from neighboring towers and hence steep fronted waves must be used. Results are given of tests on a laboratory model and of field measurements. (Science Abstracts).

300. Marx, C. T., "Some Problems of Aluminium Connection," Elect. Energy 1, 109-12 (Dec., 1956).

Methods and problems of connecting aluminium are discussed, and attention is drawn to differences in practice between copper and aluminium connection. (Science Abstracts).

301. Mason, W. P., "Adhesion Between Metals and Its Effect on Fixed and Sliding Contacts," ASLE Trans. 2, 39-49 (1959).

By studying the coefficient of adhesion as a function of the applied stress, Amonton's law of friction was verified from the adhesion side, thus confirming the Bowden-Tabor theory of stick-slip friction. Adhesion between metals due to compression, occurring over a finite time, is essential for such connections as the solderless wrapped connections and is important for contacts left under pressure in the same position for a length of time as in printed circuit type connections. Adhesion between metals caused by both compression and shear is the cause for mechanical seizure, plowing, and wear experienced in sliding contacts. (Battelle Technical Review).

302. Matsumura, H. and Takahashi, M., "On the Oxide Films and Contact Resistances," J. Inst. Elect. Commun. Engrs. 45, 613-16 (May, 1962). In Japanese.

Investigations of the relation between the thickness of the oxide film and the contact resistance of copper exposed to the air in a room are described. The thickness of the oxide film was measured by Drude's method, using elliptically polarized light. The results obtained at different room temperatures are shown graphically. The contact resistance increased rapidly at first as the oxide film formed, and then only slowly. Using the measured values of film thickness, the contact resistance was calculated from tunnel effects and film conductivity and compared with the measured values, with satisfactory agreement. (Science Abstracts).

303. Meissner, H., "Measurements on Superconducting Contacts," Phys. Rev. 109, 686-94 (Feb. 1, 1958).

The contact resistance between crossed wires was measured as a function of the current at various temperatures in the liquid-helium range. Most contacts were stable enough to establish a "diagram of state", i.e. determine curves of constant resistance in I-T space. The following facts were established: (1) The critical temperature of contacts between clean wires of tin is suppressed by about 0.2°K due to the pressure on the contact; (2) The addition of a copper layer on one or both of the wires reduces the critical currents, but hardly influences the critical temperature. This can be understood if one assumes that the density of the superconducting electrons decreases in the copper layer, thus producing an increase in the penetration depth. At layer thicknesses of several hundred angstroms the penetration depth becomes large compared to the contact radius, and the critical current v. temperature curve approaches that of a very thin wire; (3) Contacts between tin and copper wire below the critical temperature and at low currents show a constant resistance, which rises sharply at a critical current. Graphs of this quasi-critical current as a function of the temperature were obtained; (4) Clean contacts between tin and indium usually behave as one would expect from the foregoing. In one case out of three, however, the resistance was strongly dependent on the current at a temperature as high as 4.2°K. Plotting the low-current values of the resistance as a function of the temperature showed a behavior as if one of the contact materials had a critical temperature of 5 to 6°K. A search of the literature revealed that the Sn-In system has two intermetallic compounds. The compound In_6Sn_2 was prepared, and was found to have a critical temperature of about 5.5°K. Since the contacts were closed at 4.2°K and no possibility of transfer of metal from one side to the other existed, it must be assumed that the proximity of the tin to the indium is sufficient to produce partial superconductivity by way of long-range correlation of the electronic wave-functions. (Science Abstracts).

304. Meltin, Ben S., "A Method of Measurement of the Internal Series Resistance of a Capacitor Under Surge Conditions," Proc. Inst. Radio Engrs. 37, 690-3 (June, 1949).

When a capacitor is discharged through a low load resistance the stored energy is dissipated internally and in the load in the ratio of the internal and external resistances. An experimental method of using this, and a semi-graphical method of interpreting the results are described. (Science Abstracts).

305. Miller, J. H., "An Inductronic Double Bridge," Trans. AIEE 76, 198 (1957).

The instrument constitutes an alternative to the Kelvin double bridge and is primarily intended for checking 4-terminal resistances such as shunts. Identical d.c. amplifiers with resistance feedback to the inputs are connected across the standard and the test shunts. These amplifiers are of the type where the d.c. input is converted into a.c., amplified and phase-rectified. The two outputs are connected together in a differential network which includes either a pivot-type ratiometer or a servo-type self-balancing ratio indicator. By altering the value of one of the feedback resistors, shunts with current ratings different from that of

the standard can be checked. Accuracy is of the order of 0.1-0.05%. A modified form of the equipment can be used for low resistance measurement. (Science Abstracts).

306. Miller, N. B. and Boruff, V. H., Evaluation of Ultrasonic Test Devices for Inspection of Adhesive Bonds. Martin Marietta Corp., Baltimore, Md., Final progress rept. no. 12. AD-295 553 (31 Dec 62).

Selected ultrasonic, nondestructive test instruments were evaluated for their capability to detect bond strength variations in bonded structures. An initial investigation for the Bureau of Naval Weapons was supplemented by an international research program sponsored by the Structures and Materials Panel of AGARD. This report contains nondestructive test data from participants in the international portion of the program. Destructive tests have not been completed. While the final evaluation of the effectiveness of the instruments must await the destructive test results, it appears that the instruments can detect glue line porosity, thickness variations in the adhesive bond and unbonded or void areas and bond strength loss due to exposure to elevated temperatures. The instruments are not effective in the detection of substandard bonds due to poor surface preparation of undercure of the adhesive. (ASTIA Technical Abstract Bulletin).

307. Millian, K. and Rieder, W., "Contact Resistance and Contact Surfaces," Z. Angew. Phys. 8, 28-34 (1956). In German.

An experimental investigation of the resistance of an electrical contact consisting of crossed cylinders. The dependence of the resistance on the contact metal (copper, silver, tungsten), on surface treatment, contact load, and the growth of surface films is examined. (Science Abstracts).

308. Minin, G. P., "Measurement of the Resistance of an Earthing Scheme," Energetik 11, 35 (Nov., 1962). In Russian.

In the absence of special apparatus for measuring earthing resistance of portable electrical equipment associated with boring derricks for geological survey the simplest method of measurement is the ammeter and voltmeter method. The equipment required and two alternative connections of instruments and electrodes are described. Examples illustrate determination of the required instrument range and resistance values of probe and auxiliary electrodes. (Science Abstracts).

309. Mocsary, J., "A Study of the Contact Resistance Between Copper and Silver," Elektrotechnika 49, 275-80 (Sept., 1956). In Hungarian.

Basic features of differently shaped electrodes are discussed and the results are described of a series of tests. The tests were carried out on copper and silver contacts of different size and shape. The effect of surface conditions, contact pressure, and vibration, is shown. (Science Abstracts).

310. Monashkin, M. R., "Preparation of Aluminum Conductors for Stable Electrical Connectors," Trans. Amer. Inst. Elect. Engrs. III 78, 729-32 (1959).

Describes the measurement of aluminium contact resistances between strips of aluminium, receiving different scratch brushing and compound treatments, under varying pressures applied by means of a hydraulic press.

The difference in resistance between scratch brushing through the compound and compound applied after dry scratch brushing immediately before assembly is negligible. The increase in resistance due to oxide build up is not significant up to 5 hours on EC aluminium surfaces. A heat cycle test, which is described, indicated that a one-bolt parallel groove clamp, using compound, up to 10 minutes after dry scratch brushing, will perform satisfactorily. (Science Abstracts).

311. Monteath, G. D., Whythe, D. J., and Hughes, K. W. T., "A Method of Amplitude and Phase Measurement in the V.H.F.-U.H.F. Band," Proc. Inst. Elect. Engrs. 107B, 150-4 (March, 1960).

A null method has been devised for measuring changes in the amplitude and phase of the transmission characteristic of a network at any frequency in the range 41-1000 Mc/s. A commercial instrument, designed for admittance measurement, is used with only slight modification for this application. Its subsequent use as an admittance meter is unaffected. The measurement of phase can be made to within about $\pm 3^{\circ}$, unless a large variation of amplitude is encountered when reading accuracy limits the accuracy of phase measurement in the regions of small amplitude. If the error in a measurement is regarded as a vector, then, with any amplitude variation, the maximum value of the magnitude of this error vector is about 6% of the full-scale reading of the instrument. (Science Abstracts).

312. Morgan, V. T. and Vaughan, D. W., "The Testing of Compression Fittings on Steel-Cored Aluminium Conductors for Overhead Lines," Proc. Instn. Elect. Engrs. 109A, 144-50 (June, 1962).

Although midspan joints and anchor clamps for overhead power lines are designed to satisfy stringent specifications, failures occur due to faulty manufacture or erection. Compression fittings are now the only types being fitted by the Central Electricity Generating Board, and statistics are given of their relatively low rate of failure. The usual mechanism of failure is by overheating of the steel core by the current it is forced to carry when high-resistance contacts exist between the aluminium strands of the conductor and the fitting. The testing of fittings during erection or on unenergized lines can be performed by resistance measurement, with suitable precautions, by radiographic examinations, or by magnetic location methods. On energized lines, the fitting can be tested with a hook-on voltmeter or thermistor, or with an infrared bolometer. The results are given of resistance and bolometer tests on 132 kV lines in South-East England. The two methods detected a similar percentage of defective fittings. It is concluded that failure of fittings can be practically eliminated if care is taken during manufacture and erection. The testing during erection and at regular intervals during service should ensure that no further faults occur. It is recommended that all jointers be properly trained. (Science Abstracts).

313. Muller-Hillebrand, D., "Flat Contacts Under High Contact Pressure in Chemically Corrosive Atmospheres," Elektrotech. Z. 77, 860-3 (Dec. 1, 1956). In German.

The mechanical deformation of bar-type and other conductors under high contact pressure is important for low contact resistance and the actual conduction takes place through cracks in extraneous layers which afford

corrosion protection. Corrosion of copper by sulphurous atmospheres is promoted by humidity, and may be reduced by excluding fresh air and drying the air in the room. The protective effect of Ni and Cr coatings is satisfactory, but electrically inferior to Sn and Ag. (Science Abstracts).

314. Neklepaev, B. N., "Investigation Into the Contact Properties of Aluminium Conductors in Secondary Circuits," Elekt. Stantsii 10, 77-82 (Oct., 1960). In Russian.

The use of Al in secondary (control and protection) circuits has been limited by its behavior as a connector. A series of Al conductor-lug-terminal combinations was subjected to a test programme which included temperature cycles and subjection to humidity, a saline bath, vibration and short-circuited current. The results of these tests are given, and the contact voltage plotted for each phase of the tests. The worst operating conditions for Al conductors were found to be aggressive (acid or alkaline) surroundings, varying humidity, large ambient temperature variation and applications where they are subject to significant vibration. Their use in sections of 2.5 mm^2 or less is not recommended due to lack of mechanical strength. However, the contact quality can be improved by the use of quartz- (or zinc-) vaseline paste, and the tendency toward plastic deformation countered by some form of spring washer. (Science Abstracts).

315. Newsome, J. P., "A Q-meter Method of Measuring Very Low Reactances at High Frequencies," Electronic Engng. 27, 494-8 (Nov., 1955).

The test impedance is connected into the Q-meter measuring circuit through a mutual inductance of "step-up" transformer; a technique is developed which allows very low values of capacitive and inductive reactance to be measured. Details are given of a circuit designed to measure down to 0.003 μH at 1 Mc/s. (Science Abstracts).

316. Nielsen, J. O., "A New Z-ϕ-Impedance Meter," Teleteknik 9, 162-8 (Dec., 1958). In Danish.

The meter is based on an improved version of the Grützmacher bridge. In its ordinary form this bridge is subject to error at high frequencies and impedances and is unsuited for measurement of earth-balanced unknowns. In the new bridge one terminal of the variable resistance R_N and one terminal of the unknown impedance Z_x are connected to one generator terminal, the other being connected to the centre point of one winding of a differential current transformer. The ends of this winding are connected via changeover switches to the other sides of R_N and Z_x. An ammeter across the other winding of the current transformer measures vector difference and individual currents on manipulating the changeover switches, and from these currents the phase angle and impedance can be deduced. A higher accuracy of adjustment is obtained using a special zero method described. (Science Abstracts).

317. Nielsen, J. O., "A New Z-ϕ Impedance Measuring Instrument," Ingeniøren 4, 37-45 (June, 1960).

Describes the principles of a new type of impedance measuring instrument similar to the well-known Grützmacher impedance measuring bridge, and characterized by a simple and rapid adjustment procedure, direct reading of $|Z|$ and φ, a wide measuring range (1Ω to 1 MΩ), a wide frequency range (30 c/s to 300 kc/s), a wide test-current range (1μA to 1A), and an accuracy of measurement better than 1% and 0.5°. The new instrument is also applicable to measurements of balanced-to-earth impedance, and to

measurements with superposed d.c. A theoretical discussion of the systematic errors of measurement is given, and the magnitudes of such errors are estimated. (Science Abstracts).

318. Niemiaho, H., "Assembly of Heavy Busbars," Kraft o. Ljus 33, 181-5 (Sept. 9, 1960). In Swedish.

The mechanical working of the busbar material is reviewed briefly. Types of joints are discussed; their overlapping is determined by the need to reduce the total resistance $R_k = R_y + R_h$, where R_y is the contact resistance and R_h the "dispersion" resistance, dependent upon the curvature at the joint. Bolting of joints on 200 mm busbars with 7/8 in. bolts with a 200 mm overlap proved adequate, the pressure then being not more than 17 kp/cm^2 (kp = kg force); the recommended pressure is 30 kp/cm^2. Spring-type busbar constructions are also considered, designs for 8.5 kA a.c. busbars and for a 15 kA rectifier being illustrated. (Science Abstracts).

319. Niewiadomski, C. and Olszewski, M., "Cold Welding in Electrical Engineering Practice," Przeglad elektrotech. 30, 183-90 (May 21, 1954). In Polish.

Two suitably cleaned surfaces of some metals weld permanently when subjected at room temperature to pressures of sufficient magnitude. The theory of this cold welding is outlined. Metals and alloys suitable are listed. Details of surface cleaning methods, also of design of tools for welding of bars, sheets, pipes and wires are given. Cold welds of aluminium busbars have lasting high mechanical strength and low electrical resistivity. (Science Abstracts).

320. Nifontoff, N., "Remarks on the Comparison Between the Study of an Imperfect Contact and the Experimental Results Concerning Thin Metal Films," C.R. Acad. Sci. 238, 1200-1202 (March 15, 1954). In French.

Discusses the theoretical interpretation of some experiments on the electrical resistance of imperfect contacts, and examines the possibility of regarding a granular metallic film as a group of imperfect contacts. (Science Abstracts).

321. Oeding, D. and Ufermann, J., "Earthing of High-Voltage Transmission Towers," BBC Nachr. 44, 367-94 (Oct., 1962). In German.

With a view to determining the contribution of overhead earth wires to the improvement of earthing and fault conditions in a system with solidly earthed neutral, the characteristic impedances of different types and arrangements of earth wires with and without additional counterpoise wires are evaluated. Interference with parallel low-voltage lines and the current and voltage conditions as the result of an earth fault at a great distance from and close to a substation are examined. The effect of the earth wire on the potential gradient about a tower and the effective resistances of different types of earthing arrangement are investigated. The necessary mathematical formulae are developed and the results are presented in a large number of curves. (Science Abstracts).

322. Ogawa, T., "Measurement of the Electrical Conductivity and Dielectric Constant Without Contacting Electrodes," J. Appl. Phys. 32, 583-92 (April, 1961).

A method is developed whereby electrical conductivity and dielectric constant of semiconducting and dielectric materials can be measured without contacting electrodes. A specimen suspended in a rotating field with a fine fibre is rotated by the torque proportional to the electrical conductivity or the imaginary part of its complex dielectric constant, and the torque exerted on it by a linearly polarized field is proportional to the real part of its dielectric constant. An analysis of the method and some preliminary measurements of conductivity, photoconductivity, the dielectric constant of cadmium sulphate crystals and the dielectric loss of the lamella containing CdS powder are presented. The latter shows the photodielectric effect. (Science Abstracts).

323. Oudin, J., "New Developments in Pulse Technique for the Examination of Cables," Onde élect. 32, 163-9 (Feb., 1954). In French.

Two methods of increasing the sensitivity of pulse testing techniques are discussed. It is shown that for a sharp pulse signal in noise, the minimum signal-to-noise ratio for detection is of the order of 1%. In this analysis the Weber-Fechner law is assumed to apply to the minimum brightness difference visually detectable on a c.r.o. trace. With the use of a Comte "amplitude-phase corrector", in order to maintain a sharp pulse-edge, signal amplitudes of 1% of noise have been observed. A second method of increasing the sensitivity is by a mechanical correlation system which has the advantage that it is self-recording. These techniques will have applications to the acceptance testing of cables and to the study of installed submarine cables as they age. (Science Abstracts).

324. Oudin, J. "Pulse Analysis of Cables and Its Developments," Onde élect. 34, 573-83 (July, 1954). In French.

Discusses the advantages of pulse testing of cables as opposed to conventional harmonic analysis and describes the principles of pulse-testing apparatus. Methods of testing by pulse transmission and by pulse reflection are considered and possible types of visual display are discussed. It is necessary to introduce compensation for phase distortion

while improvement in s./n. ratio (at the expense of information velocity) can be effected by the use of suitable filters. (Science Abstracts).

325. Owens, G. E., Electrical Contacts in Space Environment. An Annotated Bibliography. Lockheed Aircraft Corp., Sunnyvale, Calif., Special bibliography no. SB-61-23; Rept. no. 3-77-61-1. AD-258 424 (May 61). 84pp.

A bibliography is presented which is the result of a survey of recent literature pertaining to electrical contacts in a space environment. It supports a laboratory investigation into the effects of strong ultraviolet radiation, hard vacuum (10 to the -8th power mm Hg or less), and low temperature (-50 to +200F) upon moving electrical contacts operating at currents in the milliampere-microampere range and at contact potentials up to a few millivolts. The bibliography includes references to work antecedent to the laboratory investigation, even though such work may not have been carried out within the specified range of conditions. The 169 references are arranged alphabetically by personal authors in 3 categories: (1) books, (2) reports, and (3) journal articles. An index of secondary personal authors and corporate sources is provided, in addition to a subject index. (ASTIA Technical Abstract Bulletin).

326. Pankove, J. I., "Superconducting Contacts," IRE Trans. Electron. Devices ED-7, 137-41 (July, 1960).

The microscopic size of the contact between two crossed superconducting wires offers a practical way to make a class of superconducting devices which are operated at high speed by very small currents. The critical current through the contact can be modulated by a current flowing along one or both of the crossed superconductors. Several device possibilities are presented. (Science Abstracts).

327. Parish, A. R., "Aluminium and Aluminium Alloy Busbars," Aluminium and Its Alloys, 204-18, 322-66.

Aluminium has been used for busbars, to a limited extent, for more than 30 years, but fears still exist about methods of jointing the metal, and its mechanical properties. The recent introduction, by a number of aluminium manufacturers in this country, of special electrical conductor alloys with substantially improved mechanical properties and without too great sacrifice of conductivity, has largely removed the latter problem. Describes a number of load cycle and short circuit tests on electrical purity aluminium, aluminium alloy and copper joints made in a number of ways. Successful joints were made both by scratch brushing under grease and by using a proprietary jointing compounds. The latter is a most attractive method and seems to have great promise. Test results and experience all tend towards the idea that aluminium can be used as a conductor without encountering the many difficulties forseen by most engineers. In the present situation, with a substantial economic advantage for aluminium, there is every reason for its use in suitable cases. The widespread adoption of Al for busbars is retarded by three factors; its lower conductivity, and lower strength, relative to copper, and the supposed difficulty of making satisfactory joints. The incentive to investigate these problems arises from economics, since aluminium busbars are much less expensive than copper at the present time. Considerable design work and testing has been done to obtain answers to these questions, and it is hoped that this information may be of general interest. No information has been included on outdoor applications of aluminium busbars since no such installation is known in Britain. It is believed, however, that experimental work has been done, and it is hoped that details will soon be published. (Science Abstracts).

328. Parmenter, R. H., "Theory of Superconducting Contacts," Phys. Rev. 118, 1173-82 (June 1, 1960).

The BCS theory of superconductivity is generalized to the case of a position-dependent energy gap (at the absolute zero of temperature and in the absence of magnetic fields) The BCS integral equation for the energy gap goes over into an integro-differential equation. The latter has nontrivial solutions (i.e. finite energy gap) even for the case of normal material ($V = 0$). Expressions are obtained for the energy gap, for the volume energy density, and for the surface energy density at an interface, for both normal and superconducting material. These results are applied to a number of problems involving superconducting contacts. When a thin slice of normal material is sandwiched between bulk superconductors, it is found that the slice acts superconducting for

thicknesses less than about 10^{-5}cm. When a thin slice of superconductor is sandwiched between bulk normal material, the slice acts like normal material for thicknesses less than about 10^{-5}cm. The energy gap at the free surface of a bulk superconductor may differ by as much as 30% from its constant value deep inside the material, the former being either larger or smaller than the latter, depending on the value of N(0)V, where N(0) is the density of one-electron states of a given spin at the Fermi level in the normal metal. (Science Abstracts).

329. Pavlides, P. K., "In-Service Temperature Measurement of the Amortisseur Winding of Large Frequency Changers," Trans. AIEE 75, 1436 (1957).

A description with photographs and sample temperature records of tests and testing techniques developed to measure the in-service temperature on the damper windings of the 25 cycle, single-phase generators of two large frequency changers, which had frequently given trouble due to high temperature and fatigue. Because of difficulties experienced with other methods of temperature measurement, a radiation pyrometer was used to obtain comparative temperatures on the two generators, one of which had been fitted with a redesigned damper winding. The temperature of the damper winding short-circuiting segments was obtained by comparing the degree of infrared radiation, detected by a photoelectric cell via a quartz window and an optical system, with the radiation from a thermostatically controlled oven, which was used as a standard for calibration purposes. Auxiliary equipment included means of amplification and conversion, so that the signal obtained could be shown as average temperature on a recording instrument, or traces could be obtained on a magnetic oscillograph, showing the temperature at the ten individual poles as well as check points from the oven. During the tests a continuous record of generator loading conditions was obtained by recording instruments. (Science Abstracts).

330. Pearlston, C. B., "Case and Cable Shielding, Bonding, and Grounding Considerations in Electromagnetic Interference," IRE Trans. Radio Frequency Interference RFI-4, 1-16 (Oct., 1962).

Some of the basic techniques in electromagnetic interference reduction are those of bonding, grounding, and shielding. Often, the proper techniques are employed without a full understanding of the rationale behind the techniques, and often the theory is understood but imperfectly put into practice. This tutorial paper attempts to assemble concisely the theory and techniques relating to shielding, bonding, grounding, and cable selection. (Science Abstracts).

331. Pech, H., "Ground Resistivity Measurement for the Telecommunication Engineer," Cables et Transm. 12, 325-43 (July, 1958). In French.

A review is given of a relatively large number of papers relating to ground resistivity, measuring methods and dependence on frequency, atmospheric conditions, geological nature of soil and ground undulation. The Schlumberger method is described and practical application details for telecommunications are given. (Science Abstracts).

332. Pender, J. T., "Electrical Contacts," Elect. J. 156, 1064-68 (April, 1965).

Discussion of the following: Contact mechanism, materials, desirable properties, contact wear, voltage-temperature relations.

333. Peterson, D. A., Design and Development of a Watertight Low Loss Stable RF Cable. Times Wire and Cable Co., Inc., Wallingford, Conn., Engineering rept. 216-D. AD-299 862 (30 June 62). 96pp.

A watertight version of RG-217/U was designed, developed and manufactured. The cable has been subjected to waterpressure greater than 1500 psi without leakage. The watertightness technique does not affect the electrical or mechanical properties of the cable. The attenuation is not increased and the cable is still flexible at -65 F. The cable has been subjected to heat aging, flexing and cold bending without increasing its attenuation. During the development and testing of the watertight cables several points were uncovered. The rapid attenuation increase in cables at frequencies above 4 GC can be controlled by the braid construction. A silver plated braid of small strands follows a normal attenuation curve right up to 10 GC. A braid factor for computing the effect of a braid upon a cable's attenuation was derived and verified against the measured attenuation of the sample constructions. (ASTIA Technical Abstract Bulletin).

334. Plante, P., "Electrical Coupling by Aluminium and Copper Contacts," Bull. Soc. Franc. Elect. 9, 504-16 (Sept., 1959). In French.

Contacts in the form of bars, especially if made of aluminium, show a progressive deterioration under the action of the current. With a view to reducing this deterioration, the effects of pressure and of various prior treatments of the metal surface were examined, and are here described. (Science Abstracts).

335. Pocock, W. E., "Aluminium Finishes for Use in Electronics," Electronics 32, 58-59 (Feb., 1959).

Applications, process details and properties in tabular form. (Battelle Technical Review).

336. Pohl, R., "A Matching Measuring Apparatus for the Frequency Range 30-240 Mc/s," Tech. Mitt. BRF 6, 33-6 (March, 1962). In German.

A measuring device, functioning on the principle of a bridge circuit, enabling the measurement of standing wave ratio (s.w.r.) of any passive bipoles related to s.w.r. of 60 Ω. Indicating accuracy is better than ±5% of final deflection. (Science Abstracts).

337. Polaert, R., "A New Admittance Measuring Bridge for Electronic Servicing," C.R. Acad. Sci. 253, 414-16 (July 17, 1961). In French.

The bridge consists of three parallel arms each fed by a variable amplitude generator, all three of which are of the same phase and frequency. The balance condition is when the total current is zero. A practical circuit is described. (Science Abstracts).

338. Ponomarev, D. S., "Measures in the Fight Against Corrosion of Steel-Aluminium Conductors," Elekt. Stantsii, 80-1 (July, 1961). In Russian.

Steel-aluminium conductors running along coasts or the banks of salt lakes are particularly vulnerable to corrosion. To prevent this, it is

necessary to "insulate" the steel cores from the aluminium cores, and such insulation can be effected in a variety of ways: Braid and a bituminous coating is unstable, but will nevertheless prolong the life of the conductors to a significant extent. Braid and polyisobutylene is both effective and stable under all atmospheric conditions. A third form of insulation quoted involves the replacement of the normal galvanized steel cores by cores coated with aluminium which are particularly durable under all conditions of operation. (Science Abstracts).

339. Popovic, V., "Representation and Measurement of the Argument and the Modulus of an Impedance by the Cathode-Ray Oscilloscope," Onde élect. 34, 376-80 (April, 1954). In French.

A measuring circuit is described in which the plates of a c.r.t. are fed with proportionate voltages to show both relative phase angle and magnitude. Using polar co-ordinates, R and ϕ are shown as a screen trace, by angle of axis and loop width. The theory is given, with an outline circuit diagram. (Science Abstracts).

340. Powell, R. L. and Abound, A. A., "Electrical Contact Resistance of Copper-Copper Junctions at Low Temperatures," Review of Scientific Instruments 29, 248 (1958).

The contact resistances of various bolted copper joints were measured at liquid nitrogen and liquid hydrogen temperatures. The copper was tested in oxidized (stock-shelf) or cleaned condition. The contact resistance values were obtained by measurement of the potential drop across a contact when a known current passed through the contact. After correction for the resistance of the bulk material, the values were as low as 0.1 micro-ohms.

341. Powell, R. C., Jickling, R. M. and Hess, A. E., "High-Frequency Impedance Standards at the National Bureau of Standards," IRE Trans. Instrumentation I-7, 270-4 (Dec., 1958).

Impedance standards and techniques used in the frequency range from 30 kc/s to 300 Mc/s are described. This paper covers the primary standard and how it is obtained, comparison methods used in calibrating work standards and instruments, and finally equipment used to make measurements for other laboratories. A survey showing instruments and standards involved, limitations on standards presently available, in both range and accuracy, and problems involved in accurate calibration is included. (Science Abstracts).

342. Proctor, R. F., "A Bridged-T Impedance Bridge for the V.H.F. Waveband," Proc. Instn. elect. Engrs. 99, 47-50 (April, 1952).

Describes three simple impedance bridges for frequencies of the order 50-100 Mc/s. These bridges measured the unknown impedance direct in the form R + jX, where R is its resistance, and X its reactance. The use of a bridged-T network and the connection of the impedance standards in parallel have enabled the stray admittances to be treated readily. Two of the bridges described are suitable for the measurement of the "direct" impedance between the two live terminals of a 3-terminal network. They

possess the additional advantage that no input or output transformers are required in their construction. The third bridge is suitable for the measurement of impedances which are balanced to earth. (Science Abstracts).

343. Pullen, J., "Measurement of the Resistance of Light Duty Electrical Contacts," Proc. Instn. Elect. Engrs. 109A, 220-3, 228-30 (June, 1962).

In light-duty contacts failure is caused less frequently by erosion than by high resistance due to contamination of the surface. The best guide to the degree of contamination of a contact is obtained by measuring its resistance in such a way as to avoid damaging the surface film, even if the normal use of the contact may entail such damage. A 4-terminal method of measurement should be used in order to separate the resistance of the contact from that of the switching device as a whole and its connections to the measuring network. The conditions in which the separation is physically meaningful are considered, and a simple calculation indicates where the connections should be made in a typical case. Theoretical arguments, supported by experiment, are given for limiting the test voltage to 10mV. The current need not be limited provided that the circuit is de-energized during make and break to prevent damage to surface films by inductive voltage peaks. If this is not done the current must be limited to a very small value, with serious loss in sensitivity. (Science Abstracts).

344. Pulsifer, V., Bonding Materials, Metallic Mating Surfaces, Low RF Impedance. Armour Research Foundation, Contract AF33(038)-23583. AD-61987 (November, 1954).

The objective of work done on this project was to develop a gasket material which will prevent radio frequency current from escaping at joints in closed containers. The material to be developed is also required to form a gas tight joint. Metal elements imbedded in rubber were made and tested. Results of this investigation with various materials and their rf conductivity revealed certain design principles which are involved in successful gasket performance.

To be successful, a gasket material must provide conducting paths between the flange surfaces. It is important to avoid radial conductors which run parallel to the flange surfaces because these paths will conduct rf current to the outside of the container and cause the container to act as an antenna. Each metal conductor through a gasket must have enough pressure on it to make electrical contact with the flange metal. If too many conductors are used, the pressure on each contact will not be great enough to provide electrical contact. Peak performance is obtained with the optimum number of conductors required to carry the current and provide the necessary break-through contact. The mechanical properties of the metal elements and the sealing agent must be such that after sufficient clamping pressure has been applied to establish electrical conducting paths, the remainder shall be sufficient to provide sealing pressure.

A pre-formed gasket design was developed which reduced the rf impedance below that for any previously available gasket materials. Cements were developed which even further improve the low impedance characteristics

under the same conditions. The testing was carried out over a frequency range from 0.15 mc to 150 mc. Flange pressures from 50 to 200 psi were used throughout the tests.

No direct relationship was found between dc resistance and rf impedance of a gasket.

345. Quinn, P., "Electroplated Contacts," Engl. Elect. J. 14, 48-56 (June, 1955).

The varied duties of contacts, e.g. low resistance and ability to withstand arcing, are reviewed, with notes on the choice of contact materials, especially precious metals, and on selection of appropriate manufacturing techniques. The major features of plating processes are tabulated for Ag, Pd, Au, Rh and Pt with some remarks on alloy plating. (Science Abstracts).

346. Raabe, H., "Application of Cupal Sheet (Al Clad with Cu) in Electrical Communications," Fernmeldetechn. 23, 75-77 (May 20, 1942).

Applications include use in housings of h.f. apparatus; for earthing of circuits; covering transmitters, to shield against the aerial field; coils for h.f. technique (Al clad on one side only, the coil being wound so that the Cu is inside); to replace Al for winding the outer tube of h.f. cables; as foil, for heavily loaded blocking capacitors. Cupal must not be heated for any length of time above 400°C. (Science Abstracts).

347. Raine, P. A., "Jointing Aluminum Cable--Methods of Wiping and Soldering," Elec. Rev. 148, 529-531 (March 16, 1951).

Aluminum sheath is degreased with trichlorethylene and the oxide film removed by filing. A tinning solder (90 per cent Sn; 10 per cent Zn) then adheres to the Al surface at 200 C., without the use of flux. The tinned surface is then used as the base for a wiped joint, using a low Sb content (max. 0.3 per cent) wiping solder. Severe mechanical tests prove the strength of the Al solder bond. Conductor joints are similarly affected using Cu ferrules. (Science Abstracts).

348. Ramachandra Rao, H. N. and Chetty, T. N., "A Method of Correlation of Measured and Calculated Resistance of Grounding Systems: A Single Driven Rod," J. Cent. Board Irrigation Power 19, 197-206 (March, 1962).

It is essential to determine at least approximately the resistance of a grounding arrangement before actual installation. Resistivity values used for the calculation of resistance is often the source of large error. The resistivity value obtained is a function of probe spacing. The problem is to choose a resistivity value such that the calculated resistance will be approximately equal to that measured. A solution is outlined for a grounding system consisting of a single driven rod. Field tests have been carried out to establish a relation between the probe spacing and the length of a driven rod. The chief conclusion is that by choosing a probe spacing corresponding to the length of a driven rod, the calculated resistance will be approximately equal to the measured resistance. The average value of resistivity to various depths was explored at three different places by expanding the probe spacing. (Science Abstracts).

349. Ratcliffe, P. M., "Modern Bridge Techniques," Marconi Instrumentation 4, 167-175 (Sept., 1954).

A review.

350. Rayner, G. H. and Felton, A., "Accuracy in A.C. Measurements," J. Instn. Elect. Engrs. 7, 141-4 (March, 1961).

The practical system of electrical measurements is built up from the basic reference standards. The accuracy attainable depends greatly on how close the quantity being measured is to the basic standards, and, to a lesser degree, on its magnitude. The authors, who are at the N.P.L., deal in turn with material standards, with resistors, capacitors, inductors, with voltage and current measurements (including transfer instruments), the measurement of power and energy, and with sources of supply for test purposes. In each case the best accuracy obtainable for different orders of magnitude and different frequency ranges are indicated. (Science Abstracts).

351. Reese, John P. and Boruff, Von H., Evaluation of Ultrasonic Test Devices for Inspection of Adhesive Bonds. Martin Co., Baltimore, Md., Summary rept. AD-265 235 (Aug 61).

Selected ultrasonic, nondestructive test instruments were evaluated for their capability to detect bond strength variations in adhesive bonded structure. A number of different adhesives and adherends were utilized. Investigations were conducted on both laboratory-scale panels and full-scale production assemblies. The instruments proved capable of detecting unbonded areas (voids), porosity and bond thickness variation. They were not effective in the detection of substandard bonds due to poor surface preparation or under-cure of the adhesive. They showed some capability of detecting bond degradation in service due to fatigue, heat exposure or corrosion. (ASTIA Technical Abstract Bulletin).

352. Reese, John P. and Boruff, Von H., Evaluation of Ultrasonic Test Devices for Inspection of Adhesive Bonds. Martin Co., Baltimore, Md., Quarterly progress rept. no. 8. AD-267 114 (July 61). 156pp.

Data indicate that all instruments are capable to some degree of detecting the presence of corrosion in a bonded joint. A preliminary analysis of data obtained from full scale production honeycomb assemblies indicates the panels can be classified generally as acceptable or unacceptable, but a direct correlation to specific bond strength does not exist. Finally, nondestructive tests on honeycomb panels constructed with faces of reinforced plastic, Ti and stainless steel revealed the presence of large voids but not that of other bond variables. Initial data from the AGARD program gave indications of the following the same general pattern, that is, bond variations of porosity, voids, and glue line thickness can be detected while variations due to poor adhesion and undercured adhesive give indications similar to those of a standard bond. (ASTIA Technical Abstract Bulletin).

353. Renardy, A., "Measurement of Impedance," Funkschau 28, 767 (1956).

354. Riddlestone, J., "The Variation with Current and Inductance of Metal Transfer Between Platinum Contacts," Proc. Instn. Elect. Engrs. 102, 29-34 (March, 1955).

A continuation of previous work. An account is given of the manner in which the metal transfer between platinum contacts breaking a 6V circuit varies with current and circuit inductance. Curves of the net transfer are given for currents and inductances in the ranges 1.8-7.6A and 0.6-117μH respectively. The net transfer consists of up to four different types of transfer superimposed one on another, namely "bridge," "short arc," "long arc" and "reversed short arc" transfers. The existence of the fourth type of transfer had been observed previously by Dr. A. L. Allen for currents of 10 and 20 A. It is shown that the build-up of pips on the contacts varies in steepness with the nature of the transfer. Some suggestions are given as to the mechanism of the different types of transfer, but at present a complete explanation cannot be given. Consideration is given to the practical application of the results, and it is shown that under some conditions the life of platinum contacts could be improved by controlling the effective circuit inductance at break to a value of about 0.6μH. (Science Abstracts).

355. Riddlestone, J., "Metal Transfer Between Palladium and Silver Contacts at Low Inductances," Rep. Brit. Elect. Res. Assoc.(1955). 10 pp.

Gives results for transfer between contacts of Pd and Ag breaking a 6 V circuit carrying currents between 3 and 15 A with inductance in the range of 0.7 to 96 μH. Curves are given for the mean cathode gain and the growth of pip steepness for the two metals. The results are compared with those for Pt under similar conditions and it is inferred that transfer between metal contacts is generally the resultant of the superposition of four types of transfer, namely "residual transfer", "reversed short arc transfer", "short ac transfer" and "long arc transfer". For Pt, with the range of currents and inductances used, it is possible to observe the effect of all four types, for Pd, "residual transfer" is not apparent and for Ag only the "short arc" and "long arc" transfers are apparent. If the circuit inductance could be reduced to very small values, Pd and Ag might show the complete range of transfer. A theoretical explanation is given of the dissimilarity between the transfer for Ag on the one hand and Pd and Pt on the other. (Science Abstracts).

356. Riedel, W., "Kühle's Impedance Bridge," Siemens Austria tech. Ber. 6, 5-7 (Sept., 1954). In German.

This bridge, which includes two high-grade differential transformers, permits a simple and rapid measurement of the real and imaginary parts of unknown impedances. (Science Abstracts).

357. Rieder, W., "Hot Contacts Occurring on Switches and Bus-Bar Joints," Conf. Internat. Grands Réseaux Elect. (1956). 10pp.

An explanation of the sudden rise in temperature observed in closed contacts which have been in use for a long time, based on considerations of the rate of growth of oxide films and its dependence on temperature. (Science Abstracts).

358. Rieder, W., "The Critical Comparison of Contact Materials for Electrical Switching Apparatus," Bull. Assoc. Suisse. Elect. 53, 830-40 (Sept. 8, 1962). In German.

An analysis of the conditions which must be satisfied by the materials used for electrical contacts, showing how, from the known physical constants of various metals, their suitability, for a given purpose, may be decided. (Science Abstracts).

359. Ringstrom, C. R., "Corrosion of Contacts as a Result of Smoke-Polluted Air," Tekn.-Vetensk. Forskn. 29, 190-5 (1958). In Swedish.

Holm's theory of the mechanism of electric contact is described and curves are given showing contact resistance as a function of contact potential. Copper contacts used in communication-type circuits are subjected only to very low voltages, in telephony <1/2 V, and it has been found that corrosion films formed must not be thicker than about 100 A for reliable contact operation. In atmospheres containing SO_2 and H_2S the corrosion rate is very high, and under such conditions Cu contacts can only be used for power circuits. Silver contacts resist SO_2, but are tarnished rapidly by sulphides. Methods of preventing this are

considered, the most satisfactory being a gas-trap which reduced the atmospheric sulphide content around the contacts. Organic vapours also cause trouble with noble metal contacts, owing to their polymerization and formation of insulating deposits, palladium contact suffering most in this respect; silver, however, is the most resistant. (Science Abstracts).

360. Roch, R. and Bouzitat, J., "The Influence of Normalized Splices on the Regularity of Impedance of a 2.6/9.4 Coaxial Cable Pair," Câbles et Transm. 10, 3-10 (Jan., 1956). In French.

The splice is considered as a short length of cable with values of characteristic impedance and propagation coefficient differing from those in the cable. Expressions are derived for the effects on the propagation in a spliced cable length. A numerical example is given together with graphical data on experimentally observed resonances in a spliced cable. (Science Abstracts).

361. Rochau, E. A. and Bisson, E. A., "Iron Conduit Impedance Effects in Ground Circuit Systems," Applic. and Industr. 13, 104-7 (July, 1954).

A discussion on the results of laboratory tests to determine the impedance, under earth-fault conditions, of power-circuit conductors in steel conduit. Tests were made on conduit runs using 50 ft lengths of 3 in. and 4 in. conduit and a 500,00 cir. mil (0.39 $in.^2$) cable located centrally in the conduit; the circuit arrangements being (1) current in conduit only (remote return), (2) current in cable with remote return, (3) current in cable with conduit as return. The results are tabulated and show that in case (3) the impedance is only slightly greater than that for case (1), but in case (2) the impedance is practically twice that for case (3). Curves show the a.c. resistance and reactance of the conduit for currents of 250-1000 A. The effects of these results on earth-fault currents on 3-ph., 4-wire, 115/200 V distribution systems for large buildings are discussed, and examples are given of the non-isolation of faulty circuits and unbalanced phase/neutral voltages. (Science Abstracts).

362. Roehmann, L. F., "Low-Resistance Measurements," Instrum. Control System 33, 630-1 (April, 1960).

The principle of the Kelvin bridge is explained, and a form described which is suitable for measuring the resistance of busbars carrying heavy current, e.g. 3 kA. The bridge provides for lead balancing, which can be carried out without interrupting the main circuit. (Science Abstracts).

363. Rollins, Fred R., Jr., Study of Ultrasonic Techniques for the Nondestructive Measurement of Residual Stress. Midwest Research Inst., Kansas City, Mo., Quarterly progress rept. no. 7. AD-295 071 (14 June 62). 17pp.

Investigation of various ultrasonic techniques that may have application in the nondestructive measurement of residual stress is covered. A major phase of this program has been a study of the interaction of acoustic waves in nonlinear solids. This phase was initiated in an effort to

obtain information about subsurface volume elements. Since ultrasonic waves can be collimated into well defined beams, the intersection of two such beams can be used to define a reasonably small volume element within a relatively large specimen. We believe that a thorough study of the mutual interaction of two intersecting beams may provide heretofore unavailable information about the mechanical properties of the intersection volume. A theoretical analysis of expected beam interactions was carried out and the results have been encouraging. Some of the theoretical results to numerical data were reduced and efforts to experimentally verify the theoretical predictions were continued. A modified schlieren system was designed and partially constructed for use in studying beam interactions in transparent solids. (ASTIA Technical Abstract Bulletin).

364. Rollins, Fred R., Jr., Study of Ultrasonic Techniques for the Nondestructive Measurement of Residual Stress. Midwest Research Inst., Kansas City, Mo., Quarterly progress rept. no. 9. AD-295 072 (17 Dec 62). 9pp.

Various ultrasonic techniques that may have application in the nondestructive measurement of residual stress are investigated. During the past quarter beam interaction experiments have been continued and the first successful observation was made of scattered ultrasonic waves that originate at the 'point' of intersection. Subsequent experiments have verified a number of theoretical predictions and the scattered waves have now been detected in specimens of fused silica and polycrystalline magnesium and aluminum. The cases explored thus far include: (1) interaction of two transverse waves to produce a 'sum' frequency logitudinal waves, and (2) the interaction of a longitudinal and transverse wave to produce a sum frequency longitudinal wave. 'Difference' frequency waves have not yet been observed. We have also continued our study of optical detection techniques and the application of such methods to the beam interaction problem. The sensitivity of our equipment has been improved and excellent photographs of traveling wave packets are now obtained with comparative ease. (ASTIA Technical Abstract Bulletin).

365. Romanowski, M. and Dunn, A. F., "A Note on the Sensitivty of Electrical Bridge Networks," Canad. J. Phys. 30, 342-7 (July, 1952).

A theoretical discussion on bridges and standard resistance units, particularly applied to the Wheatstone and Kelvin double bridges over the ranges from 0.0001 to 10 Ω. Absolute accuracy of standards is given as ~0.0001%, but relative accuracy in the measurement of secular changes may be ~1 p.p.m. for 1Ω units. For the Kelvin bridge used, the net sensitivity error was found to vary from 51.4 p.p.m. for 0.0001 Ω to 0.2 p.p.m. for 10 Ω. From the theory various practical points in operation are derived, including speed of measurement. (Science Abstracts).

366. Roullier, L., "Testing of Mechanical Joints in Aluminium Conductors for Insulated Cables," Proc. Instn. Elect. Engrs. 110, 758-72 (April, 1963).

The increasing use of aluminium conductors in insulated cables has created a need for a standardized testing procedure for the evaluation of joints in the conductors. The paper proposes electrical and mechanical evaluation tests which can be used as a basis for discussion preparatory to the

formulation of a test specification. The tests are based on theoretical studies and practical experience relating to the mechanism of current transfer through an aluminium contact interface and of the thermo-mechanical stresses set up in the cores of insulated cables. For the electrical tests it is proposed that the joints should be subjected to 2000 load cycles at defined currents based on the maximum current loading likely to be experienced in service, followed by 12 short-circuit impulses of amplitude and duration dictated by the thermal limitations and bursting strength of the cables. It is recommended that a joint should be considered satisfactory if, at the end of the electrical tests, its resistance does not exceed 150% of the equivalent conductor resistance. In the mechanical test it is required that the joint should be capable of withstanding a tensile stress equal to 50% of the ultimate tensile stress of the associated conductor. (Science Abstracts).

367. Rowland, P. R., "Solderless Connections," Elect. Times 137, 491-5 (March 31, 1960).

The basic concepts involved when a ferrule is compressed onto a wire to give an electrical connection are reviewed. It is shown that certain popularly held beliefs--particularly concerning the roughness of surfaces and cold welding--are not in accordance with practice or theory. It is considered that the most profitable approach is from fundamental ideas on the structure of metals, their properties and the nature of oxide films on their surfaces. (Science Abstracts).

368. Rowland, R., "The Measurement of Feeder Irregularities by Means of Pulses," Marconi Rev. 24, 182-92 (4th Qtr., 1961).

A description is given of a method of locating and measuring irregularities in microwave aerial feeders. Irregularities of 0.03 dB s.w.r. can be detected by use of pulses of 1μs duration. Results of field use are given. (Science Abstracts).

369. Rudeforth, S., "Contact Resistance and its Variation with Current," P.O. Elec. Eng. J. 42, 65-69 (July, 1949).

Multiple tests on contacts of Uniselector were conducted over a current range of 0.22 to 4.5 amp. using a 12-v. supply. For "static" tests, a peak-millivoltmeter was used to obtain maximum values of resistance persisting for short periods after switching on the current. Multiple results are plotted in a combined graphical and statistical manner. The metallic contact condition is concluded to require a maximum of 2 v. For "dynamic" tests, a stepping rate of 10 per sec. was used, and oscillograph records showed peaks of contact resistance on vibration either from stepping magnet or from external sources. Although make-before-break switching was used, higher values were recorded than for "static" test conditions and these again increased after 250-500 switch operations. (Science Abstracts).

370. Rzymowski, E., "Measurement of the Q-Factor of Two-Terminal Network," Proc. Instn. Elect. Engrs. 109B, 678-82, 682-5 (May, 1962).

The method described has the important advantage over known methods of

Q-factor measurement in that the unloaded Q-factor of the resonator is obtained directly. It is derived from the reflection coefficient measured at the coupling cross-section of the resonator at resonance, and the frequency interval between two points of the response curve at which the reflection coefficient reaches a certain values obtained from the theory. At these two points the real and imaginary components of the impedance of the cavity are equal. The value of Q is calculated from the familiar equation $Q=f/2\Delta f$. Although the method was developed primarily for 2-terminal networks, it can also be used for transmission and reactance cavities. The loaded Q and the external Q can be calculated using the data obtained from the unloaded Q-measurement. An outline of the derivation of the formulae is also given. (Science Abstracts),

371. Sagel, K., "Electrical Contact Resistance in Copper Cable Conductor Joints," Nachrichtentech. Z. 8, 541-4 (Oct., 1955). In German.

Results of measurements on twisted, welded and soldered joints are given. It is shown that, on an average, soldered joints have the lowest resistance and smallest scatter of results. (Science Abstracts).

372. Samal, E., "Electrical and Mechanical Measurements on Contacts and Relays," Arch. tech. Messen., 281-4 (Dec., 1955). In German.

A review of methods of measuring contact resistance, contact pressure, insulation resistance and capacitance between contacts. The crossed-wire method of measuring contact resistance of materials under varying pressure is described, as well as an arrangement for life testing switches using a motor drive to enable 100,000 operations to be performed in 6 days. (Science Abstracts).

373. Sandell, D. H., "Three Steps Lead to Economical and Reliable Alunimium Buses," Elect. Wld. 148, 92-5 (Nov. 25, 1957).

To ensure the best use of aluminium busbar the conductor must meet the load requirements, the mechanical arrangement should be adequate and joints and connections must be properly made. Details are given of the electrical and mechanical properties of aluminium conductor. The advantages of integral web channel bus are outlined and alternative methods of making joints and connections described. (Science Abstracts).

374. Sanders, W. J., "Laboratory and Field Evaluation of Connectors and Other Accessories for Aluminum Conductors in Severe Marine Environments," Trans. Amer. Inst. Elect. Engrs. III 78, 1342-53 (1959).

Describes a programme of tests and field studies initiated mainly with the objects of evaluating and appraising available commercial accessories for use with aluminium conductors and developing new types of fittings suitable for aluminium conductors in the most severe environments. The tests showed that (1) platings on a connector only increase the damaging effects of galvanic corrosion; (2) bronze and copper body connectors are not suitable for use with aluminium conductors in severe marine environments; (3) split-bolt type connectors tend to be weak and do not provide the spring action required to absorb thermal shocks and maintain a stable connection; (4) parallel-groove type connectors will provide a satisfactory connection for aluminium conductors providing that the design of the connector shields the conductor from contacting the steel bolt directly or through a narrow salt bridge; (5) aluminium bolts eliminate the problem of conductor attack from the inside of the connector; (6) compression type connectors will provide satisfactory and serviceable connections if the design is such that contact area and degree of compression are adequate; (7) the use of contact sealing paste or grease is an advantage. (Science Abstracts).

375. Sandomirskii, V. B. and Smilga, V. P., "On the Possible Role Played in Adhesion Phenomena by the Double Electrical Layer Formed at the Solid-Solid Interface," Fiz Tverdoga Tela 1, 307-314 (Feb., 1959). In Russian.

Theoretical. Formulae for the force of adhesion were derived for the cases of an n-type semiconductive layer (a) in contact with metal, and (b) between two metals. The analysis was based on the standard method of the so-called "physical barrier-layer" (uniform distribution of the donor atmos across the thickness of the semiconductor), and it was assumed that the work function of the semiconductor was greater than that of the metal. It was inferred from the results that, in addition to molecular forces, electrostatic forces associated with the formation of the double electrical layer may also play an important part in adhesion between solids. (Science Abstracts).

376. Sanford, F. E. and Fisher, J. I., "Tests Point to Aluminum Connector Standards," Elect. Wld. 149, 38-40, 92 (March 31, 1958).

A detailed description of tests carried out by the Armour Research Foundation to provide information fundamental to the preparation of a specification, for industrial purposes, for the performance of connectors for Al conductors. The testing apparatus consisted of flat pl tes, 1-1/4 in. sq., clamped to the conductor, with arrangements to include bolt strain-gauges and thermocouples, the voltage drop at the contacts being measured on an oscillograph. The measurements were taken periodically during heating and cooling tests, the std. duration being 400 cycles, but some tests were extended to 1200 cycles. The results of 250 tests are summarized graphically in 4 families of curves. (Science Abstracts).

377. Savel, J., "Contacts and Contact Materials for Very Low Voltages and Currents. II. Properties of Contacts, Sliding Contacts, Materials," Slaboproudy Obzor 17, 274-7 (1956). In Czech.

Continuation of the author's previous investigation (Science Abstracts B, Abstract 2710-11/1955). Single and double contacts were investigated. The following parameters were measured: the contact resistance (in new and artificially-aged contacts), noise voltage, cleaning (breakdown) voltage and the effect of dust. The parameters were also measured for 12 different shapes of the contacts. The results are reported in 6 tables. Measurements were also carried out on six different telephone selectors, for which the following sliding-contact parameters were investigated: the resistance, noise voltage, mechanical wear and the effect of lubrication. The materials recommended for "stationary" contacts are: Au, Pt, Pd, Rh, Au + 5% Ni, Pt + 5 to 30% Ir, Pt + 8.5% Ni, and Pt + 5% W. The materials are also suitable for sliding contacts, but it is also possible to employ: "hard silver", Ag + 2 to 5% graphite, Ag + 30% Pt, and Ag + 30% Pd. (Science Abstracts).

378. Savel, J., "Contacts and Contact Materials for Very Low Voltages and Currents," Slaboproudy Obzor 15, 531-538 (1954). In Czech.

The experiments reported aimed at determining the most suitable contact materials, the requirements to be fulfilled being: low resistance, stability at low pressures and under variable checmial conditions, and absence of semiconducting layers. Six groups of materials were investigated: Ag, Au, Pt, Pd, and their alloys, W and sintered materials with W as a predominant element, and sintered materials with Ag predominant. The contacts had the form of a rivet head w th diameter 2 mm, height 0.6 mm,

and radius of curvature 1.5 mm. Resistances of 44 different materials were measured under a variety of conditions, namely: (1) resistance of new contacts R_0, as a function of pressure P, $R_0 = f(P)$, the current being I = 50 ma; (2) $R_0 = f(I)$ at a pressure of 15 g; (3) resistance of the contacts aged artificially in an atmosphere of H_2S as a function of pressure, $R_s = f(P)$, at I = 50 ma and (4) $R_s = f(I)$ at P = 15 g. The results are reported in four graphs and two tables. (Science Abstracts).

379. Savel, J., "Contacts and Contact Materials for Very Low Voltages and Currents, (2)," Slaboproudy Obzor 15, 579-586 (1954). In Czech.

The following additional measurements are reported; (1) noise voltages across the contacts caused by mechanical vibration of the contact springs; the measurements were made on artifically aged contacts under conditions of constant current and pressure; (2) clean-voltages, i.e. the voltages necessary to break down the insulating layers on the contact surfaces and (3) resistances of aged contacts at very low direct and alternating (100 kc/s) currents. The results are indicated in three additional tables, the methods of measurement being described and illustrated by diagrams. It is concluded that only Au, Pt, and Pd are suitable for the contacts; the maximum amount of nonprecious metals which can be added to Au, Pt, and Pd without causing adverse effects should not exceed 30%. (Science Abstracts).

380. Sawicki, J. "A Compensated Thomson (Kelvin) Bridge with Substitution," Rozprawy elektrotech. 7, 334-53 (1961). In Polish.

A double Kelvin bridge is first balanced with a standard resistance close to the one to be measured. The unknown is then substituted and the bridge is rebalanced by means of an additional e.m.f. in series with the galvanometer. The resistance change is determined with certain simplifying approximations in terms of the compensating e.m.f., the bridge current, and the bridge arm ratios. An analysis is given of the level of approximations, the absolute measurement accuracy and the optimum design of the bridge. The method is useful for testing of a large number of similar resistors of the order of 0.01 Ω or larger and has the advantage of using conventional laboratory equipment. In a practical example measurements by the above method are compared with those obtained by a balanced Kelvin bridge. (Science Abstracts).

381. Schaefer, L. P., "Electrical Grounding Systems and Corrosion," Trans. Amer. Inst. Elect. Engrs. II 74, 75-83 (1955).

An outline is given of accepted practice in earthing networks. The corrosion of electrodes that may result is then studied at length, including the remedial action of cathodic protection by providing a counter e.m.f. in the soil. A low-resistance earth connection is best for all purposes, including reduction of electrode corrosion, but alternate high and low resistance coils and local changes in dampness enhance corrosion. In some cases corrosion has been reduced by using neoprene-covered cables. Painted steel frames in concrete, and the subject of tower footing resistance is dealt with at length, together with lightning and surge protection and static earthing, with examples. (Science Abstracts).

382. Scholes, N. P. and MacFarlane, J. E., "Measurement of Impedance at Audio Frequency," Electronic Technol. 38, 106-107 (March, 1961).

383. Schreiber, O. P., "Reliable Electrical Contact Theory Applied to RFI Control," Symposium Digest, Fourth National Symposium on Radio Frequency Interference, San Francisco; June 28-29, 1962.

The author discusses dry contact theory briefly and considers methods of reducing constriction resistance. Gold, silver, tin, cadmium and lead are considered as being suitable for dry contact material. Aluminum, copper, steel and stainless steel are considered not suitable due to corrosion films. The results of constriction resistance measurements at D.C. with crossed wires and various materials is presented. Best results are found to be (in order of best performance:) (1) Rhodium flash on silver plate on copper, (2) Tinned copper, (3) 100 microinches gold on copper, (4) 30 microinches gold on copper. Some tests were made of tin on copper alloy RF gaskets. Results look promising. Author believes any material which does poorly at D.C. can be expected to also do poorly at RF. Author believes more investigation of tin or solder materials should be made.

384. Schreiner, H. and Wendler, F., "Heating of Electric Contacts in the Stationary State," Z. angew. Phys. 13, 117-20 (March, 1961). In German.

The well-known formula relating the maximum temperature in an electric contact to the applied potential difference is illustrated by graphs and the existing data concerning the quantities which appear in the formula are summarized. (Science Abstracts).

385. Schroth, L., "Mechanical Contacts," Feinw Tech. 66, 372-374 (Oct., 1962). In German.

A survey of mechanical contacts as applied to electrical connexions. Discussion includes: construction, characteristics, resistance, vibration, wear and contact materials. (Instrument Abstracts).

386. Selzer, E., "On Certain Properties of Imperfect Electric Contacts with Application to Earthing and to Methods of Recording Earth Currents," C. R. Acad. Sci. 242, 884-7 (Feb. 13, 1956). In French.

A short discussion of contact resistance with applications to contacts between metals and liquids. (Science Abstracts).

387. Shackman, N. and Thomas, R. W., "Pressure-Type Connectors for Aluminum and Copper Conductors," Trans. Amer. Inst. Elect. Engrs. III 80, 991-5 (1962).

A study of the connection to aluminum conductor indicates that high pressures are required to effect a satisfactory connection and that relative movement between strands during tightening greatly assists in reducing contact resistance. A properly designed connector will incorporate means for applying high pressures with considerable distortion of the conductor. Heat-cycling tests which included mechanical stressing were found to be valuable in comparing designs. An aluminum-bodied connector with an aluminum screw gave satisfactory performance with both copper and aluminum conductors. (Science Abstracts).

388. Shekel, J., "R.F. Cable Characteristics Measured with a Q-Meter," Electronic Engng. 26, 540-2 (Dec., 1954).

The velocity ratio of the cable is determined by measuring the electrical length of a 1/2 λ sample at about 50 Mc/s. Characteristic impedance is determined from the change in input susceptance for a small change in frequency near resonance, and attenuation by a measurement of the decrease in Q on connecting the cable. Charts show the errors introduced by simplifying assumptions. (Science Abstracts).

389. Shepherd, Ralph E., Measurement of Electromagnetic Wave Attenuation Characteristics of Portable Shelters Composed of Pliable Reflecting Materials. Pickard and Burns, Inc., Needham, Mass., AD-234 762 (15 Apr 59). 21 pp.

A model portable shelter was analyzed under 3 different operational conditions: (1) the batting and ground cloth carefully joined to avoid openings; (2) the batting readjusted and the ground cloth removed; and (3) the frame attached to the ground leads at each corner (less ground cloth). The results for the condition with ground cloth in place show a degree of attenuation which, with moderate adjustments should result in a shelter with adequate shielding or attenuation to fully protect personnel and/or equipment as required. For the 1,000 mc situation, as an example, the degree of attenuation achieved is at least equal to that of certain all-metal shelters available commercially. Despite the high degree of attenuation achieved, internal leakages were detected at the following regions: (1) the center seam (gaps due to type of construction and fastening); (2) area near joints of ground cloth and underlapped sides of shelter (no electrical bonding provided); and (3) zippered entrance (cloth parts of zipper acting like a slot antenna) causing coupling of external energy to interior of shelter. The use of a conducting groundcloth, which provides an average of 30 db attenuation up to 10,000 mc, is shown to be essential. The failure of the shelter to attenuate evenly and effectively over all areas studied was not due to poor selection of reflective material, but rather to a need to re-arrange the material to achieve complete electrical contact at all points. (ASTIA Technical Abstract Bulletin).

390. Shone, A. B., "An Admittance Display System," Electronic Engng. 34, 530-6 (Aug., 1962).

The equipment described is capable of providing an automatic display, on a c.r.t., of impedance or admittance over a swept frequency band. The equipment can be mounted a considerable distance away from the unknown impedance and the information can be presented normalized to any desired value of reference impedance and corrected for any intervening cable length between the display equipment and the termination being measured or adjusted. (Science Abstracts).

391. Short, G. W., "Two-Signal Bridges. Reducing Stray Admittances," Electronic Technol. 37, 452-6 (Dec., 1960).

An inconvenience of simple a.c. measuring bridges is that the bridge oscillator and the detector cannot have a common terminal; the connections to one diagonal of the bridge must be "floating". If two oscillators of

different frequencies are used, a simple modification to the usual bridge arrangement makes it possible for the input and output to have a common terminal without shorting one arm. The new arrangement can be used to reduce stray admittances. Some circuit arrangements enable the bridge to be remotely situated, both input and output signals being conveyed on one pair of wires. (Science Abstracts).

392. Shotter, G. F. and Elliott, N., "Testing of Earth-Continuity Conductors," Rep. Brit. Elect. Res. Assoc. Ref., 14 (1951).

The behaviour of joints such as occur in earth-continuity conductors is examined with special reference to existing Regulations regarding such conductors and to test methods. Tests are described both on earth-continuity conductors in service and on simple contact arrangements designed to simulate joints. (Science Abstracts).

393. Simmonds, R. K. and Bhagwat, P. G., "A Simple Impedance Comparator Utilises Three-Limb Transformer," Elect. Times 142, 877-9 (Dec. 13, 1962).

The comparator described consists of a shell-type r.f. transformer core with a 1000-turn primary coil on the centre limb, and a 500-turn secondary coil on each of the two outer limbs. The secondary coils are connected in series opposition through a voltmeter. The primary coil is energized from a 1 V, 1 kc/s source, and by carefully clamping the core, and adjusting resistance and capacitance trimmers across the secondary coils, the voltage difference between the secondaries on open-circuit can be reduced to 0.15 mV. By connecting an unknown impedance across one secondary coil, and known adjustable values of R, L or C across the other coil, the settings of the latter when the secondary voltages are balanced give directly the values of the components of the test impedance. The highest accuracy obtainable is stated to be 0.01% when measuring resistances of the order of 1000Ω or capacitances of the order of 1 μF. For resistances between 100Ω and 10 kΩ it is 0.5%. For capacitances of 0.1 μF, 0.01μF and 500 pF, it is 0.025%, 0.1% and 4%, respectively. (Science Abstracts).

394. Simons, K., "Sweep-Frequency Techniques for Measuring High-Frequency Impedance," Electron. Design 8, 64-67 (July 20, 1960).

Author presents method of impedance measurement using sweep-frequency generator, standard attenuator and C.R.T. Method is simple but requires test jig and high speed DPDT RF switch. Gives some applications and nomograms to speed calculations. 2 appendices.

395. Singh, A. P., "Joints in Aluminium and Aluminium Alloy Busbars," Rep. Brit. Elect. Res. Assoc., Rep. Z/T118 (1959).

Variation in contact resistance with contact pressure was examined. Various surface preparations were used, including abrasion under petroleum jelly, tinning, silver plating and coating with patented jointing compounds. The effect of temperature on joint resistance was also examined. Copper busbar joints were examined mainly to act as a standard of reference for the aluminium bars. It was found that other things being equal, rolled-aluminium bars gave a lower joint resistance than extruded bars and the majority of the experiments were carried out with them. (Science Abstracts).

396. Smith, G. E., "Anomalous Skin Effect in Bismuth," Phys. Rev. 115, 1561-3 (Sept. 15, 1959).

High-frequency (23.5 kMc/s) surface resistance measurements were made on plane surfaces of single-crystal bismuth at 2° K as a function of orientation. Extreme anomalous skin effect conditions were found to prevail, allowing details of the Fermi surface to be deduced from Pippard's theory. In Shoenberg's model of the electron band, components of the inverse effective-mass tensor divided by the Fermi energy are found to be α_1/E_e = 9.10, α_2/E_e = 0.038, α_3/E_e = 4.7, and α_4/E_e = 0.38 (in units of 10^3/eV). These results are in essential agreement with values obtained from de Haas-van Alphen experiments and cyclotron resonance. The number of ellipses is definitely established to be six and the number of electrons found to be $N = 5.5 \times 10^{17}/cm^3$. The parameters for the two hole ellipsoids are found to be $\beta_1/E_h = \beta_2/E_h = 1.5$ and $\beta_3/E_h = 0.12$. Assuming Shoenberg's value E_e = 0.0177 eV, the value E_h = 0.00112 eV is calculated from specific heat data. It is also found that the reflection of carriers from the surface of the sample is predominantly specular in contrast to diffuse reflection found in other metals. (Science Abstracts).

397. Snowdon, A. C., "Studies of Electrodynamic Forces Occurring at Electrical Contacts," Trans. Amer. Inst. Elect. Engrs. I, 80, 24-8 (1961).

The repulsion forces between a conical moving contact and a flat surface are evaluated and a nomograph is produced assuming plastic deformation of the contact face. Experimental results on 1 in. dia. copper contacts agree with the calculation to within 20%. (Science Abstracts).

398. Soderman, R. A., "Impedance Measurements in the 50-2,000 Mc/s Range," Radio-Electronic Engng. 16, 3-6, 25 (July, 1951).

The admittance-meter described compares the unknown with conductance and susceptance standards by adjustable sampling loops. An oscillator and detector are supplied. A crystal mixer is used as detector so that the receiver can be tuned to a frequency of 30 Mc/s, and so be free from direct pick-up from the oscillator. Ancillary equipment includes variable length lines and balancing transformers. An account is given of methods of measuring the parameters of radio components. (Science Abstracts).

399. Sondheimer, E. H., "The Theory of the Anomalous Skin Effect in Anisotropic Metals," Proc. Roy. Soc. 224, 260-72 (June 22, 1954).

The theory of the anomalous skin effect in metals is extended to a uniaxial metal crystal containing two energy bands in each of which the energy surfaces are ellipsoids of revolution about the crystal axis. Explicit formulae are obtained, for the extreme anomalous limit, giving the dependence of the surface impedance on the orientation of the crystal axis, both for a plane metal surface and for a circular wire. The form of the anisotropy of the surface impedance is found to depend upon the axial ratios of the spheroidal energy surfaces and upon the ratio of the electron free paths in the two bands. Wide variations in behaviour are possible, and the surface impedance may show a high degree of anisotropy even when the d.c. conductivity is almost isotropic (as with tin at low temperatures). The results are evaluated numerically for tin, and the

surface conductivity of a circular wire is found to show the minimum observed by Pippard; the parameters can be chosen to give reasonable agreement with Pippard's results. (Science Abstracts).

400. Soper, P. F., "Carbon-Brush Contact Phenomena in Electrical Machinery," Proc. IEE 96, 645-654 (August, 1949).

A theoretical investigation into the change in contact resistance when sliding occurs. It is assumed that the current is conducted by a series of points on the surface which are continually changing and the problem is considered on the basis of electron emission. The effects of brush quality, polarity, pressure, surface film, etc., are discussed. Test results are given. (Science Abstracts).

401. Sorrows, H. E., Ryan, W. E. and Ellenwood, R. C., "Evaluation of Coaxial Slotted-Line Impedance Measurement," Proc. Inst. Radio Engrs. 39, 162-8 (Feb., 1951).

Most u.h.f. impedance measurements are made by detecting the voltage-standing-wave ratio (v.s.w.r.) and nodal position in a slotted section of coaxial transmission line. Sources of error in these measurements are discussed and methods of eliminating or evaluating them are presented. It is shown that the maximum error due to structural defects in determining the relative voltage can be predicted experimentally for most standing-wave machines and that the resulting max. error in the v.s.w.r. is 2x the max. error in determining the relative voltage. The resulting max. error in the nodal position and, also, the fractional errors in the load resistance and reactance due to the errors in the v.s.w.r. and nodal position are calculated and presented in graphical form. (Science Abstracts).

402. Spayth, F. J. and Heil, V. E., "Electrical Contacts II," Electrical Manufacturing 54, 122-127 (Oct., 1954).

Performance factors of four basic contact materials--pure metals, true alloys, Ag semi-refractory compacts, and compositions of refractory metals with Ag or Cu. Properties and applications. (Battelle Technical Review).

403. Spengler, H., "Silver-Cadmium Alloys as Electrical Contact Materials and Their Thermal Improvement by Oxidation," Metall. 10, 628-632 (1956).

Binary alloys of silver with 10 and 15 per cent cadmium were oxidized in air for periods up to 300 hr at 800 C, thereby producing the surface reaction Ag-Cd solid solution = Ag-CdO together with internal oxidation-formation of some CdO precipitate inside the material. The thickness (d) of the surface film, and the amount of internal oxidation, depend on the temperature, time (t) and O pressure, and $\alpha t^{1/2}$. The optimum electrical properties are obtained when the surface films are 0.05 to 0.5 mm thick, the specific electrical resistance rising, and its temperature coefficient decreasing; there is, also, improved resistance to arcing; the mp of the material increases; its ultimate tensile strength, and elongation decrease, while the microhardness of the surface increases to approximately twice the normal value (that is, of the original alloy), but falls with increasing distance below the surface, this decrease corresponding to a decrease in CdO particle size below the surface--approximately

$ad^{1/2}$. Photomicrographs illustrate the surface films obtained. Thus Ag-CdO contact materials can be satisfactorily produced by oxidation of Ag-Cd alloys, as well as by pressing and sintering Ag-CdO powders. (ASTM Bibliography and Abstracts on Electrical Contacts).

404. Spry, W. J. and Scherer, P. M., "Copper Oxide Film Formation at a Sliding Carbon-Copper Interface," Wear 4, 137-49 (March-April, 1961).

An experimental study is reported of the surface chemistry of a Cu_2O film formed on a copper slip ring in sliding contact with various electrographitic-carbon brushes during the passage of electric current. It was found that the effective temperature at which oxidation occurred was the bulk temperature of the copper. Several electrographitic brushes caused changes in the steady-state thickness of the copper oxide. A proposed explanation of these effects is given in terms of previous information about the oxidation mechanism of copper. (Science Abstracts).

405. Stickley, G. W. and Smith, C. O., "Mechanical Properties of Aluminum Electrical Bus," Trans. Amer. Inst. Elect. Engrs. 73 III, 100-106 (April, 1954).

Results in tabular form of tensile, compressive and bend tests on aluminum busbars of rectangular and tabular form and of various tempers. Resistance to creep is also noted. Temperature effects appear negligible up to 100 C; subzero temperatures show a slight increase in tensile strength with no evidence of embrittlement. Tests on welded joints showed no increase of electrical resistance. Tensile strength of butt-welded joints varied from 10,000 to 23,000 $lb/in.^2$ (Science Abstracts).

406. Sunde, Erling D., "Earth Conduction Effects in Transmission Systems," D. Van Nostrand Co., Inc. (1949).

407. Swerdlow, N. and Smith, K. N., "Welded Aluminum Conductors in Isolated Phase Bus," Trans. AIEE 77, part III, 337 (1958).

An investigation into the conductivity of the joints, special requirements and weld soundness of these bus bars. The conductivity of the welds was largely equal to the conductivity of the solid metal. Minimum space requirements, particulars of connector design, tables of heat runs are given. Details of welding procedure with recommended electrodes, speeds, currents, voltages, shielding gases, required qualifications of welding operators, safety practices, and methods of protecting the welder when operating in the open, methods of controlling the weld quality, examples of difficult weld joints are quoted. Welded aluminium conductor joints in insulated phase busbars are just as effective and reliable as bolted silver-plated aluminium joints and simple to assemble in the field, all small components and joint compounds being eliminated. Suitable portable welding equipment is available. The tungsten arc process is particularly suitable. (Science Abstracts).

408. Sze, W. C., "Measurement of Voltage Ratio at Audio Frequencies," Trans. Amer. Inst. Elect. Engrs. I 76, 444-9 (1957).

Designed for work on precision ratio transformers, the equipment comprises a bridge, of which two arms are the transformer windings, the others consisting of parallel resistors and capacitors, with similar arms arranged as a guard circuit. Two auxiliary circuits are used, a Schering bridge for measuring phase angles and a Wheatstone bridge for precise measurement of voltage ratios. The circuit is analysed and a wiring and switch diagram is given. Ratios from 1:1 to 100:1 can be measured with an accuracy of $\pm$0.005%. (Science Abstracts).

409. Tagg, G. F., "The Measurement of Earth-Loop Resistance," Proc. Instn. Elect. Engrs. 104A, 115 (1956).

Regulations for the electrical equipment of buildings call for a measurement of the earth-loop impedance and give a method by which this can be done. Several instruments have been devised and are available to carry out this test, but all draw their testing current from the mains and are thus liable to serious errors. Records taken with a recording voltmeter show that in most cases there is already a voltage drop in the neutral conductor, which is varying continuously and rapidly. It is shown both theoretically and by practical tests that instruments of this character can have errors under these conditions amounting to 100% or more. Any instrument intended to carry out these tests must be such that it will give the correct value despite the presence of the continuously varying voltage drop in the neutral. An instrument is described which draws its testing current from its own hand-driven generator and is free from these errors. The regulations also call for a measurement of impedance, but it is suggested that in most cases the difference between impedance and resistance of an earth loop is so small that an instrument measuring resistance will be sufficient. (Science Abstracts).

410. Takeuchi, G., Sagara, T., and Yamaguchi, T., "A New Earth Resistance Measuring Set," Bull. Electrotech. Lab. 24, 95-9 (Feb., 1960). In Japanese.

The circuit diagram is given for a new instrument designed to operate from 6 V d.c. supplies for the measurement of earth resistance by the four-electrode method. A current source using a vibrator inverter is used together with a thermionic-tube bridge. Electrode spacing of 300 to 600 metres may be used. (Science Abstracts).

411. Takeuchi, G., Sagara, T., Yamaguchi, T. and Kojiro, T., "On the Vacuum Tube Type Earth Resistivity Measuring Device," Bull. Electrotech. Lab. 26, 251-7 (April, 1961). In Japanese.

Describes a vacuum tube type earth resistivity measuring device applicable to resistivity measurement in electrical prospecting. The device is composed of a power supply unit and a measuring unit. The output characteristics and the current wave form of the power supply unit are given, and the effects of earth resistance, external noise and proportionality of current transformer on the accuracy of the device is discussed. The performances of this device are as follows: the frequency and output are 18 c/s, and 20 VA respectively and the power supply unit is of 6 V, 4 A d.c.; the input impedance, measuring ranges and accuracy of the measuring unit are respectively 3 MΩ, 0.00005~25200 Ω(X1000, 100, 10, 1, 0.01, 0.001) and ±2% (minimum: 0.00005 Ω). (Science Abstracts).

412. Tamai, Y., "On the Contact Resistance Between Surface-Oxidized Metals in Repeated Sliding," Wear 1, 377-383 (April, 1958).

413. Tanii, T. and Toma, K., "Measurement of Constriction Resistance By Gold Plating Method," Rev. Elect. Commun. Lab. 10, 531-42 (Sept. - Oct., 1962).

Constriction resistance of contact between two bodies which are different in their electric conductivity of surface layers was analytically obtained, and was compared with contact resistance of bodies plated with thin gold. As a result of these investigations, it was found that, constriction resistance is measurable by the gold plating method even in the air. It was also found that the constriction of crossed rods can be closely approximated by classical theory developed on the assumption of elastic deformation. (Science Abstracts).

414. Thinius, E., "Measurement of the Reflection Coefficient of Television Lines and Apparatus," Nachrichtentech. Z. 10, 548-50 (Nov., 1957). In German.

After a brief discussion of reflection phenomena and of the formula for the refl. coefficient p, a simple experimental method of determining p of a cable by means of a wobbulator is suggested and described. The voltage response appears as a horizontal line in the case of a perfect match, as a uniform sinusoidal function in the case of a resistive mismatch (p is then derived from the ratio of max.--min. amplitude to mean value) and finally as a fluctuating function, corresponding to the common case of a complex mismatch; the phase angle can be derived from the inspection of maxima and minima. Various oscillograms and impedance charts with frequency as parameters are reproduced and discussed. (Science Abstracts).

415. Thomas, B. Mac A., "Amplitude and Phase Measurement in the V.H.F. Region," Electronic Engng. 34, 546-8 (Aug., 1962).

A method was devised by which a commercial v.h.f. impedance bridge may be used to measure changes in the amplitude and phase of a network in the frequency range 100 to 500 Mc/s. The instrument may also be used as a slotted line, a full 360° phase-shift being covered at 102 Mc/s and above. (Science Abstracts).

416. Thompson, G. J. and Behr, S. H., "Aluminum Bus for Shipboard Application," Trans. AIEE II 78, 239-47 (1959).

Investigations were made into two grades of aluminium conductor to determine the variations in joint resistance for different methods of surface preparation. It is concluded that for marine use a hard aluminium alloy, silver-plated overall and coated with joint compound before assembly will make a satisfactory bus bar arrangement. An account of the behaviour of busbar under short circuit, corrosion, vibration and shock conditions is included. (Science Abstracts).

417. Thorp, J. S., "R.F. Conductivity in Copper at 8 mm Wavelengths," Proc. Instn. Elect. Engrs. III 101, 357-9 (Nov., 1954).

Measurements of r.f. conductivity in copper have been made at 8 mm wavelengths. It is shown that, in addition to the known effect of surface roughness, the conductivity may be considerably reduced below the d.c. value by surface layers of low conductivity and stress in the bulk

material. This can be overcome by etching and annealing, or by a process designed to cover the surface layers. Under suitable conditions the d.c. conductivity can be obtained. (Science Abstracts).

418. Tipple, P. M. and Henisch, H. K., "Thermal Effects at Point Contact Diodes," Proc. Phys. Soc. 66, 826-832 (Oct., 1953).

A thermoelectric method is described which enables the temperature of a point contact to be determined. Measurements have been made on a germanium diode at various positions on the voltage current characteristic, and it is found that voltage turnover occurs at a critical contact temperature, which is constant for a given specimen. The result also shows that temperature gradients in the neighborhood of a hot point contact can increase the contact resistance. An interpretation of this observation is proposed. (Science Abstracts).

419. Tischer, F., "The Accuracy of Microwave Impedance Measurements," K. Tekn. Hogsk. Handl. (1950). In German.

The basic theory is developed with emphasis on impedance and a definition given of standing-wave ratio and matching error. For small matching errors approximate formulae are deduced. With this theory as background the following instruments and their accuracy are discussed: reflectometer directional couplers, impedance bridges, comparators. The method using a standing-wave indicator is more exactly discussed since it gives the greatest accuracy. An exact scheme for the measuring equipment is developed and the error sources are separated in two groups, the line discontinuities of the standing-wave meter (s.w.m.) and the voltage divider which contains the probe impedance. The errors caused by these influences are calculated and means for eliminating them developed. A partial elimination is possible by using the proper complementary equipment to the s.w.m., but the greatest part can only be eliminated by new development. A method is given of measuring the maximum error by two tests. The results have been used for the development of a precision s.w.m. and a rotating, automatically indicating meter for the S-band using 7/8 in concentric lines. The error of the s.w. ratio is 0.5% for the precision meter and 3% for the rotating meter. (Science Abstracts).

420. Toop, I., "Earth Continuity Tester," Elect. Rev. 163, 25-6 (1958).

An earth continuity tester for use by installation inspectors is described. The primary purpose of the tester is to check the impedance of the loop circuit from the earth pin of a three-pin general purpose outlet via the earth circuit to the supply transformer and return through the neutral conductor. Other uses of the tester are discussed. (Science Abstracts).

421. Tseitlin, L. A., "The Skin Effect in an Array of Conductors of Rectangular Cross-Section," Zh. tekh. Fiz. 26, 2771-7 (1956). In Russian.

The problem of skin and proximity effects was solved theoretically by J. D. Cockcroft for one and two conductors and by G. V. Der-Shvarts for an array of conductors of any dimensions. The last solution involves some non-tabulated functions with parameters related in an involved way with geometrical dimensions of the array. The author discusses

the problem of thin conductors of semi-infinite length which permits of an analytical solution and compares it with the one of conductors of finite length. It is shown that the treatment used for semi-infinite conductors produced results nearly identical to those derived for conductors of finite length. The same method is applied to conductors of finite thickness and after the evaluation of energy and current the formulae for R/R_0 and L are derived. (Science Abstracts).

422. Tsuchiya, K., "Testing of Materials for Light-Current Contacts," J. Inst. Elect. Engrs. Japan 74, 145-9 (Feb., 1954). In Japanese.

The life of light-current contacts is affected by initial conditions such as internal stresses, amount and distribution of impurities and non-uniformity of the surface. The process of deterioration of contacts can best be determined by recording automatically the contact resistance at each make and break. In the conventional test, the contact resistance is measured at long intervals which prevents the full characteristic being determined and requires a long period for completing the life test. The apparatus described, however, provides a complete record of the variation of the contact resistance. It consists of a voltage amplifier, a current amplifier, a synchronous adjustment unit and a power unit. The voltage drop across a pair of contacts is taken to the amplifier and hence to a recording equipment. In order to suppress the excessive voltage developed at contact break, a triple-twin valve was installed in the adjustment unit. Test results on Ag, Cd and other contacts are described. (Science Abstracts).

423. Tsuchiya, K., "A Standard Method for Life Testing Low-Current Contact Materials," J. Inst. Elect. Engrs. Japan 74, 1075-8 (Sept., 1954). In Japanese.

The testing apparatus for such contact materials must meet any electrical or mechanical requirement. This applies far more in the case of these contacts than for heavy-current contacts since here more accurate regulation of the working conditions and greater number of readings are required. Results obtained are tabulated together with those on heavy currents and the differences as regards material, electrical and mechanical factors are brought out. Test procedure and the handling of the data are also given. (Science Abstracts).

424. Tsuchiya, T., "Method of Analysis of the Quantity of Material Loss and the Value of the Contact Resistance in Life Tests and Methods of Life Testing for Low-Current Contacts," J. Inst. Elect. Engrs. Japan 74, 1064-74 (Sept., 1954). In Japanese.

No standard testing methods have been developed for low-current contacts. Statistics show that the lives of such contacts are determined by the consumption of the contact material and by the contact resistance, while with heavy current contacts the most important factor is the tendency to weld. As the measured values are more scattered in the case of weak current contacts, a statistical approach is necessary. The material consumption must be considered as a population of two variables, since it occurs simultaneously at both positive and negative contacts. The values of contact resistance during a life test form a time series. A description

is given of such a life test, which must be carefully planned as to the number of measurements and the interruptions for determining contact resistance, the determination of the consumption curve, the measurement of the static and dynamic contact resistance, the welding characteristics, and the measurement of the operating contact resistance. (Science Abstracts).

425. Tucker, N. A., "Electrical Contact Materials," Elect. Rev. 164, 1127-31 (June 19, 1959).

The properties and characteristics of silver, platinum, rhodium, palladium, iridium, ruthenium, osmium and gold in electrical contact applications are discussed. The characteristics of an ideal universal contact material are described. (Science Abstracts).

426. Turabi, M. M., "Soil Resistivity--Its Characteristics and Measurement," Power Engr. 12, 35-40 (Jan., 1962).

Knowledge of soil resistivity is of decisive importance in the evaluation of problems involving earth as a return conductor. The various factors affecting soil resistivity, e.g. composition of soil, temperature and moisture content, are discussed. The details are given of the several methods in practice, for the measurement of soil resistivity, viz., (1) four-electrode method; (2) direct current method; (3) guard ring method; (4) compression method; and (5) higher frequency methods. The methods are compared and recommendations are made on the basis of attainable results. (Science Abstracts).

427. Urben, T. F. A. and Sheppard, S. H., "A Method of Recording Contact Resistance Under Dynamic Conditions," Post Off. Elect. Engrs. J. 48, 240-5 (Jan., 1956).

Investigations on the comparative performance of nickel-silver and polished and unpolished rhodium-plated nickel-silver on wiping contacts for 12,160 operations showed little advantage for rhodium plating. Contact pressure tests show the superiority of a phosphor-bronze/silver bimetal combination over nickel/silver contacts. Tests were conducted with an automatic tester at 1 m A, 1 kc/s and the contact resistance was recorded in decade steps from less than 0.01 to over 10 ohms with a recording time of 100 msec duration starting 5 msec after making of contact. (Science Abstracts).

428. Vereshchagin, L. F., Zubova, E. V. and Shapochkin, V. A., "Contact Electrical Resistance for High Normal Pressures," Zh. tekh. Fiz. 32, 230-2 (Feb., 1962). In Russian.

The first results obtained on the relation between contact electrical resistance and normal pressure up to 100,000 kg/cm^2 are described. A sharp drop in electrical resistance was found to occur in the range of pressure from 0 to 10,000-15,000 kg/cm^2, related to the change in the actual area of contact. [English translation in: Soviet Physics-Technical Physics (USA), Vol. 7, No. 2, 163-4 (Aug., 1962).] (Science Abstracts).

429. Vinjar, A., "Compression Junctions for SCA Lines," Elektrotek. T. 70, 117-122 (March 15, 1957). In Norwegian.

Until 1954 experience with compression joints on aluminum and SCA lines of the Norwegian (Øosland) network had been good, but 3 breakages then prompted an investigation of their mechanical and electrical characteristics. The main cause of failure was corrosion which gave rise to increased resistance. Good junctions had resistances of about 60μΩ, bad ones 100 to 120μΩ. Resistance was measured initially by a Ductor low-resistance test set for 0 to 500μΩ and a bridge reading down to 50μΩ. Both d-c tests used were carried out by lowering the line to the ground, which was expensive. An a-c method enabling the resistance to be determined by voltage drop measurement on the live line is described. A small "cage" was suspended on the line, being hoisted up by Terylene ropes. It carried a 3-range 0 to 80 mv millivoltmeter. Readings could be taken with a telescope. Of 218 joints tested by this method over a 2-month period, 13 were found unsatisfactory and removed from service. (Science Abstracts).

430. Warham, J., "The Effect of Inductance on Fine Transfer Between Platinum Contacts," Proc. Instn. Elect. Engrs. I 100, 163-8 (July, 1953).

The paper commences with a brief review of the previous work on fine transfer between contacts. The investigation described was undertaken to find out whether there is a connection between fine transfer and the inductive energy stored in a circuit at break. The work was carried out with platinum contacts in a 6-volt circuit breaking currents of the order of 1A. The circuit inductance was controlled from 0.05 to 10 μH. The results show that there is a residual transfer independent of inductance, but that the transfer is dependent on inductance when this is greater than about 0.3 μH. In both cases the transfer results in cathode gain. It is deduced that this second transfer is due to a "short arc." Possible explanations of the two types of transger are given. (Science Abstracts).

431. Warrelmann, E., "Procedure for Testing the Mechanical and Electrical Properties of Conductor Joints and Clamps," Elektrizitätswirtschaft 55, 761-5 (Nov. 5, 1956). In German.

Mechanical tests include hardness of contact surfaces and the elastic strain under pressure. Electrical tests include voltage drops, thermal and short-circuit tests. (Science Abstracts).

432. Warshawsky, I., "Multiple-Bridge Circuits for Measurement of Small Changes in Resistance," Rev. Sci. Instrum. 26, 711-15 (July, 1955).

In the multiple-bridge circuit, first-order effects of random resistance variations occurring at the junctions of a Wheatstone bridge are eliminated by an extension of Kelvin's method, which involves adding an auxiliary resistor pair at each bridge corner at which the variations occur. The remaining second-order error, and the effects of thermals, are evaluated. The multiple-bridge technique makes possible precise resistance comparisons, and the accurate measurement of small changes in resistance of an element that is connected through switch contacts, or brushes and slip-rings. Some numerical design data are given. Elaborations of the basic circuit, and typical applications, including measurements with resistance strain gauges are described. (Science Abstracts).

433. Weedy, B. M., "The Contact Resistance of Heavy Current Contacts on Overload," Elect. Energy 2, 20-3 (Jan., 1958).

The results of research on circuit-breaker contacts of the plug and socket type to ascertain their ability to carry currents in excess of the rated for prolonged periods are given. Temperature-rise measurements on the contacts are only of value when taken with the contacts in situ, but the measurements of contact resistance are seen to be valid when obtained from tests with the contacts alone in the laboratory. With the contacts in air it is seen that effect of the oxide film which forms on the contact surfaces at overload currents is balanced by the film's possessing a negative temperature coefficient. Thus the tendency for the contact resistance and hence contact heating to increase cumulatively due to the oxide film and so destroy the contacts, is arrested and the contacts at 25% overload settled down at about 2.5 times the normal value of contact resistance. Measurements of contact resistance across surfaces oxidized by low values of direct current, e.g., 20 A are seen to given much higher values than actually exisitng when the heavy currents flow, due to the oxide

film's negative temperature coefficient. Silver plating is seen to be effective in preventing the formation of contact surface films and the contact resistance is seen to actually decrease on overload currents. As to be expected with the contacts immersed in oil the absence of air prevents an oxide film forming and the contact resistance remains sensibly constant regardless of current. (Science Abstracts).

434. Weills, N. D. and Ryder, E. A., "Thermal Resistance Measurements of Joints Formed Between Stationary Metal Surfaces," Trans. Am. Soc. Mech. Engrs. 71, 259-266 (April, 1949).

Gives the results of measurements on dry and oil-filled joints between two flat surfaces of various metals. Thermal resistance is decreased by increasing temperature and pressure, by inclusion of oil, or by plating the surfaces with a soft metal. (Battelle Library Review).

435. Weinitschke, W., "A Method of Measuring Reactances and Impedances with the Double Voltage-Divider Connection," Fernmeldetech. Z. 4, 117-21 (March, 1951). In German.

The impedance to be measured and a series-connected variable resistor form one voltage divider; a fixed resistor and a series-connected variable resistor form the other. The two dividers are connected in parallel across a suitable a.c. supply, earthed on one side. A high-impedance valve-voltmeter is switched alternately from the middle connection of one divider to the other, and the resistances are adjusted so that the voltages of the two points to earth are the same. The outer connections to the divider containing the impedance are then reversed, and the other (resistive) divider adjusted again to give voltage balance to earth. From the resistance values found in the two tests, a simple calculation gives the impedance and also the reactance. The method requires three resistances only, and is not dependent on accuracy of calibration of the valve-voltmeter. (Science Abstracts).

436. Wellard, Charles L., "Measuring Impedance of High-Frequency Resistors," Electronics 26, 176-9 (Oct., 1953).

A series of cavity resonators of similar design are employed to cover the range 2-400 Mc/s at specific frequencies. One operates at 400 Mc/s, another at 200 Mc/s, and the third at 100 Mc/s with lumped inductances added at the end of the cavity for use at 2, 10, 25 and 50 Mc/s. The input from the source employed is fed via a piston attneuator to a coupling loop in the cavity, while a capacitive probe is connected to the crystal detector. One end of the inner conductor is increased in diameter and bored out to accomodate a special micrometer. This micrometer provides a linear variable capacitor which enables increments of 0.001 pF to be measured. Resistance is measured by either the change of resistance or change of susceptance method. For the highest accuracy the cavity impedance should approximate to that of the resistor under test and accordingly adjustable padder and tuning stubs are provided to vary the impedance up to 12 kΩ at 400 Mc/s. Accuracy claimed is ±2.5%. (Science Abstracts).

437. Went, J. J., "The Electrical Resistance of Metal Contacts," Philips Techn. Rev. 4, 332-335 (Nov., 1939).

The electrical resistance of contacts depends in the first instance upon the specific resistance of the material of the contacts, the hardness of the material and the contact pressure. In addition, the properties of the surface of contact are also important. On the basis of these facts a study is made in this article of the methods by which a contact with a high resistance may be improved. (Science Abstracts).

438. Wessel, R., "A Simple Method for Investigating the Electrical Properties of the Ground for Earthing Purposes," Elektrotech. Z. 71, 339-40 (July 1, 1950). In German.

A simple method is described which enables the electrical resistance of the earth to be determined at various depths by means of measurements on the surface. (Science Abstracts).

439. Whitley, J. H., "Which Permanent Electrical Connection Should You Use?," Electronics 34, 50-51 (Jan. 25, 1963).

Eighteen different mechanical, chemical or thermal methods of joining conductors are rated in eight categories, such as electrical properties, mechanical properties or applicability to various conductors.

440. Widdis, F. C. "Scientific Electrical Measuring Instruments. A Review of Progress," Proc. Instn. Elect. Engrs. 105B, 415-24 (Sept., 1958).

Deals with the progress in the design of scientific measuring instruments since the last review was published in 1946. The upsurge in scientific and technological progress during this period has necessitated considerable development in measuring techniques. New instruments have been developed for new applications, and much effort has been devoted to improvements in existing measuring apparatus to cope with the continual demands for improved performance and reliability. In many applications a degree of accuracy is now expected from commercial instruments that has hitherto been achieved only by the most refined laboratory techniques. The paper is restricted to a consideration of those devices which are primarily of interest to the electrical engineer, or which utilize electrical measuring techniques. The most important recent developments have probably been in connection with nuclear phenomena and their applications, semiconductor devices and electronic instruments. (Science Abstracts).

441. Widl, E., "A Review of Present-Day Methods of Measurement of High-Frequency Cables," Fernemldetech. Z. 8, 262-5 (May, 1955). In German.

The various methods are tabulated and references given to more detailed descriptions. (Science Abstracts).

442. Wilfinger, R. J. and Zolotar, B. A., "Technique for Measuring Tunnel Diode Series Resistance," Rev. Sci. Instrum. 33, 693-4 (June, 1962).

A pulsed a.c. bridge circuit is described which enables a resolution of $\pm$0.001 ohm to be attained: this accuracy may be obtained by a single measurement. (Science Abstracts).

443. Wilhelm, H. T., "Impedance Bridges for the Megacycle Range," Bell Syst. Tech. J. 31, 999-1012 (Sept., 1952).

Three instruments designed for measurement on the wide-band L-3 coaxial system (0.3-8 Mc/s) are a 20 Mc/s general-purpose bridge, a 5 Mc/s Maxwell inductance bridge and a 10 Mc/s admittance bridge. The general-purpose bridge covers a few ohms to 1 MΩ ± 0.5% and uses a centre-tapped transformer of novel construction for ratio arms, a series range capacitor and deposited carbon resistors. Others cover 0.001-10μH ± 0.25% and up to 200 ± 0.01 μμF. By the use of standards covering several decades, added precision compared with most commercial types is obtained. (Science Abstracts).

444. Williamson, J. B. P., "Significance of Non-Destructive Tests of Compression Joints," Proc. Instn. Elect. Engrs. 109A, 224-8 (June, 1962).

The manner in which an initially sound compression joint fails in service is discussed, and it is suggested that one of the most important parameters affecting the life is the running temperature of the joint. It is the temperature near the contact areas which is vital, and this can, under certain circumstances, differ markedly from the bulk temperature of the joint. It is shown that in a typical joint the regions near the contact areas within which the dangerous local high temperatures occur are so small that the temperature follows the oscillations of a 50 c/s current. (Science Abstracts).

445. Williamson, J. B. P., Greenwood, J. A. and Harris, J., "The Influence of Dust Particles on the Contact of Solids," Proc. Roy. Soc. A 237, 560-573 (Nov. 20, 1956).

An investigation has been made of the manner in which two solids touch when one of the contacting surfaces is contaminated with dust. The behavior is discussed in terms of the probability that intimate contact will be established between the solids in any particular closing operation. It is shown that this probability is related in a simple manner to the number and size of the contaminating particles, to the load between the solids, and to the nature of the contacting surfaces. The manner in which a dust particle can become trapped between the approaching bodies and thus prevent direct contact occurring is considered and a simple physical model of the processes is proposed. For this model the dependence of the nature of the contact on the number and size of the contaminating particles is derived. The experimental behavior is in good agreement with that predicted. The theoretical discussion indicates that the effectiveness of the contamination in preventing direct contact should fall off rapidly if the surface roughness is increased until the height of the irregularities is comparable with that of the particles. The effect has been verified experimentally. It has also been demonstrated that there is a sharp change in the probability of the occurrence of intimate contact if the area of contact between the solids is made comparable with the cross-sectional area of the particles. The practical significance of these observations is discussed. The various possible methods of increasing the probability that direct contact will occur are considered, and general relations are given by means of which the behavior of two contacting solids under any given concentration of dust may be predicted. (Science Abstracts).

446. Wilman, C. W., "Electrical Contact Resistance Between Magnetically Attracted Bodies," Nature 172, 917-918 (November 14, 1953).

Results of experiments on light current contacts indicate that the resistance at a contact in which the members are attracted to each other by a magnetic force is less than that between members pressed together mechanically by a force of the same magnitude. Reasons are given for attributing this to a greater number of minute areas of actual contact in the case of magnetic attraction. (Science Abstracts).

447. Wilson, R. W., "The Contact Resistance and Mechanical Properties of Surface Films on Metals," Proc. Phys. Soc. 68, 625-641 (Sept., 1955).

The nature of the contact between sliding metal surfaces has been investigated by measuring the electrical contact resistance and the coefficient of friction between them. Observations were made over a wide range of conditions which extended down to very light loads of only a few milligrams so that the influence of surface films might be studies. Many noble and base metals have been investigated in both clean and lubricated states. The contact between certain typical pairs of dissimilar metals has also been studied. It was found that at loads below a few grams the oxide film on base metals prevented actual metal-to-metal contact almost entirely. At higher loads the film was disrupted, and metallic contact occurred. The change from oxide-to-oxide to metal-to-metal sliding was usually accompanied by changes in the coefficient of friction, the nature of the sliding, and the appearance of the track. The same techniques have been used to investigate the influence of the Beilby layer, by comparing the behavior of annealed and electropolished surfaces with that of worked ones. The contact between lubricated metals has also been studied over a wide range of loads and the electrical contact measurements have shown that with monobasic fatty acids a change in the nature of contact occurred as the load was increased. It was found that at heavy loads the contact resistance between lubircated metals fell to a value comparable with that of clean surfaces although measurements of the coefficient of friction suggested that the area of actual metallic contact had not increased correspondingly. These experiments have shown that the behavior of oxide, Beilby, and lubricant films on metal surfaces follow the same pattern, and that a single general picture, based on the theory of the sliding between clean metals at heavy loads, can be given which will describe their influence on the contact and sliding between metals. (Science Abstracts).

448. Windred, G., "Electrical Contact Resistance," J. Frank. Inst. 231, 547 (June, 1941).

A general review of the phenomena of contact resistance is followed by a theoretical treatment based on the assumption of the constriction of the lines of current flow through point contacts between the two metals in question. The effects of surface films and coherer action are discussed and a general theory is presented. A short account of experimental work on coherer action and the effect of contact pressure is given and contact voltage characteristics are described. (Science Abstracts).

449. Wolff, H. H., "The Accuracy of Impedance Measurements in A.C. Bridges," J. Franklin Inst. 269, 299-313 (April, 1960).

The accuracy of impedance magnitude and phase measurements in a.c. bridges is derived as a function of the null instrument sensitivity and a bridge characteristic. The influence of the bridge-length ratio and its phase angle on the measurement accuracy is treated in detail. It is especially shown that for a bridge-length ratio amount of 1, that is, $|z_1| = |z_3|$, the obtainable accuracy improves as the phase angle $\sphericalangle z_1, z_3$ increases. It is furthermore shown that the maximum impedance magnitude error and the maximum phase error occur at different bridge adjustments. Formulae for the phase angles between null voltage and bridge voltage for maximum impedance magnitude error and for maximum phase error are derived. (Science Abstracts).

450. Wollenek, A., "Contact Erosion and Limiting Current Values in Stationary High-Current Contacts," Arch. Elektrotech. 45, 357-67 (1960). In German.

A new model for representing the phenomena which occur in a stationary contact is developed. Experimental studies were made, to determine the critical conditions for the first appearance of these phenomena. (Science Abstracts).

451. Wollenek, A., "The Alteration of Contact Surfaces at High Temperatures," Z. angew. Phys. 12, 360-4 (Aug., 1960). In German.

A theoretical discussion of the progressive changes which affect the resistance of electrical contacts, with detailed experimental results for contacts made of copper and of silvered copper, under various conditions of temperature and of contact pressure. (Science Abstracts).

452. Wollenek, A., "Contact Resistance of Stationary Surface-Contacts at High Currents and Temperatures," Elektrotech. Z. 80, 306-8 (May 11, 1959). In German.

The theory of point and surface contacts is discussed, and measurements of the resistance are given, for a variety of temperatues, pressures and contact materials. (Science Abstracts).

453. Wollenek, A., "Symmetrical and Unsymmetrical Silvered High Current Contact Points," Elektrotech. Z. 80, 826-7 (Dec. 1, 1959). In German.

It was shown in previous papers that the resistance of high current contacts depends very much on the nature of the surfaces, and that the effect of silvering is considerable. The effects of varying the arrangement of the contacts, and the thickness of silvering, are studied. (Science Abstracts).

454. Wollenek, A., "The Contact Resistance of Resting High Current Sintered Alloy Point Contacts at High Temperatures," Elektrotech Z. 12, 533-563 (Oct., 1960). In German.

The contact resistance which is a function of the temperature, time, contact pressure, hardness, and technological factors was experimentally investigated for W-Cu and W-Ag alloys at temperatures up to 400 C. Results revealed a wide spread of contact resistance with composition. The enrichment of the surface layer in Cu with temperature can be kept within tolerable limits for alloys up to W/Cu = 60/40, but may produce

undesirable effects in alloys with higher W content. W-Ag contacts have, in general, lower contact resistance as W-Cu compositions especially at high contact pressure. 13 figures, 10 references. (Science Abstracts).

455. Woods, D., "A Coaxial Connector System for Precision R.F. Measuring Instruments and Standards," Proc. Instn. Elect. Engrs. 108B, 205-13 (March, 1961).

General design requirements are discussed for a coaxial connector system for precision r.f. impedance and admittance standards, bridges and measuring instruments of all types for frequencies up to 4 Gc/s. A description is given of a practical connector system which has been in use for many years at a Ministry of Aviation laboratory. The design is such that the connector system does not introduce uncertainties greater than about 3 parts in 10^4 in the admittance parameter. The residual parameters of the connector system, including the open-circuit and short-circuit conditions, are described and evaluated. Data relating to the discontinuity capacitances encountered in a practical measuring system are also given, together with formulae for the precise transformation of admittance between two planes in a uniform coaxial line. (Science Abstracts).

456. Wood, D., "A Precision Dual Bridge for the Standardization of Admittance at Very High Frequencies," Proc. Instn. Elect. Engrs. 104C, 506 (1957).

The need is stated for a more accurate means of admittance or impedance measurement in order that a general improvement can be made in the accuracy of measurement of other electrical quantities at radio frequencies. A description is given of a precision twin-T dual bridge having a range of admittance measurement associated with coaxial systems between 3 Mc/s and 300 Mc/s. The inaccuracy of measurement does not exceed 0.2% on either component of a complex admittance at a frequency of 200 Mc/s. The calibration of the bridge is absed on a range of coaxial susceptance standards whose parameters are calculated from length and time measurements. The dual feature of the bridge enables the true r.f. conductance of its internal standard resistor to be established in terms of these standards; the uncertainty of this determination is not greater than 0.1% for frequencies up to 250 Mc/s. The importance to be attached to the design of coaxial terminations is emphasized. A practical design is detailed for a coaxial terminal for precision admittance and impedance measuring instruments, and mention is made of a proposed universal coaxial connector system for precision radio-frequency measuring instruments of all types. (Science Abstracts).

457. Woods, D., "A Precision Dual Admittance Bridge for the Range 3 to 300 Mc/s," Precision Electrical Measurements, Paper 4, 29pp. Her Majesty's Stationary Office (1955).

A description is given of a precision twin-T dual admittance bridge having a range of measurement associated with coaxial systems between 3 Mc/s and 300 Mc/s. The inaccuracy of measurement does not exceed 0.2% on either component of a complex admittance at a frequency of 200 Mc/s. The calibration of the bridge is based on a range of coaxial susceptance standards whose parameters are calculated from length and

time measurements. Particulars are given of the method used for connecting the coaxial termination of the unknown admittance to the bridge terminals. (Science Abstracts).

458. Woods, D., "Admittance Standardization and Measurement in Relation to Coaxial Systems," IRE Trans. Instrum. I-9, 258-68 (Sept., 1960).

The facilities afforded by the admittance bridge and the connectors previously described have made it possible to realize designs for voltmeters, wattmeters, attenuators, and terminating resistors having not only greatly improved accuracy but also extremely wide-band frequency-independent characteristics. Various types of connector are described and also a connector line, constructed from special silver-lined and silver-overlaid precision-drawn tubes fitted with connectors at each end, which is used when physical separation is necessary between two instruments, and also to obtain accurate admittance transformations. Matching techniques are discussed and also the errors which may result from instrument mismatch. (Science Abstracts).

459. Wyant, R. A., "Measurement and Effect of Contact Resistance in Spot Welding," Trans. AIEE 65, 26-33 (Jan., 1946).

A standard arrangement of electrodes, work and press is shown. Oscillograph loops show the resistance changes as the weld progresses, with a battery and Kelvin double bridge for initial measurement before welding commences (on a.c.). Various states of preparation of the work are discussed and typical curves given connect resistance with time of treatment and time of weld. Al is chiefly dealt with, but steel and alloys of Mg, Cu and Ni are also described. (Science Abstracts).

460. Wyeth, F. H., Higley, J. B. and Shirk, W. H., Jr., "A Precision, Guarded Resistance Measuring Facility," Trans. Amer. Inst. Elect. Engrs. I 77, 471-6 (1958).

The apparatus described is a precision Wheatstone bridge provided with guard circuits, and suitable for measuring resistances in the range 100 kΩ to 100 MΩ with an accuracy of 0.01%, with 100 V applied to the bridge, and ambient conditions of 95% relative humidity. The basic insulating material used is ebonite, coated, after cleaning, with a 2% silicone in CCl_4. Guarded terminals are insulated with acrylonitrile-styrene copolymer, and their insulation resistance is $>10^{12}\Omega$ at 95% r.h. Power supplies are either a guarded battery, or an a.c. mains-operated rectifier unit with highly insulated transformers and a guard circuit. The guarded electronic balance detector will show a 0.01% change in a 100 MΩ resistor with 100 V applied to the bridge. (Science Abstracts).

461. Yates, W. A. and Queen, J. L., "Sheet and Plated-Metal Measurements With a Phase-Angle-Type Probe," Commun. and Electronics 12, 138-42 (May, 1954).

Experimental work, supported by theory, is detailed with data for the design of practical instruments. A mutual-inductance transducer is used to measure the plate impedance which for a given transducer and frequency is a function only of thickness and resistivity. Either amplitude or phase-angle measurement is feasible, but the latter has the advantage of insensitivity of transducer to metal spacing, also allowing its use with moving plates or strip without contact. Balance may be made by a null method or a so-called dynamic balance, the latter further aiding spacing insensitivity. Choice of frequency is considered for various cases, with examples on different metal and plating thicknesses for non-ferrous materials. (Science Abstracts).

462. Yeamans, W. H. and Henderson, W. L., "Tests of Static Electrical Joints," Proceedings of 1958 Seminar on Electrical Contacts, Penn. State Univ. (June, 1958).

Discussion of some tests performed on aluminum bus-bar connections, both plated and unplated. All connections are of the same size and are subjected to temperature cycling. Measurements made of current and contact potential. Wax coating used in order to better observe actual contact area. Results show resistance decreases as joint pressure increases reaching a limit outside the accuracy of the test apparatus. Author concludes silver-sulfide film on silver plated joints has little effect on operation of joint, and that thickness of silver plate has little effect. No considerations given to high frequencies.

463. Yetitto, Paul and Gorman, Richard, Feasibility Study of Non-Destructive Testing Infrared Inspection System for Bonding Flaw Detection. Perkin-Elmer Corp., Norwalk, Conn., Interim rept. no. 2. AD-259 362 (Apr 61). 168pp.

An investigation was begun to establish the feasibility of IR measuring techniques for detecting bond failures (flaws or voids) between rocket casings and the insulating liner and between the liner and the solid propellant. The IR detection principles involve (1) the injection of heat into the rocket casing over a small area surrounding the point of measurement, (2) detection of variations in wall diffusivity by the time varying emission characteristic from the region of heat application, and (3) evaluation of fluctuations of the emission characteristic by comparison of the signal to that arising from a flawless bond. Preliminary measurements were made on flat plate samples with known flaw configurations. An intensive analysis of heat flow mechanisms in bonded structures has progressed from the formal solution of partial differential equations to the creation of an electric analog model of the 1 dimensional heat flow problem. Analog results indicate that a flaw between the case and liner about 0.1 cm separation and 0.78 sq cm nominal area is detectable with a maximum contrast ratio of 6.7% between 2 and 5 sec after heat injection. A similar defect between the liner and propellant gives a maximum surface contrast ratio of 16.5% about 10 sec after heat injection. (ASTIA Technical Abstract Bulletin).

464. Young, C. H., "A Comparator for Precise Transfer Conductance Measurements," Bell Lab. Record 32, 427-30 (Nov., 1954).

The T-resistance unit used as the basis of many precision networks is readily compared to a high degree of accuracy on a comparator in which G, the network transfer conductance is defined as the short-circuit output current divided by the p.d. across the input terminals. Overall accuracy approaches 1 part in 10^7, with normal air-conditioning. A new d.c. feedback amplifier was designed having a noise level of $< 3\mu V$ for the direct comparison of two similar units. The final bridge arrangement is given, with component values. The detector used has an input resistance of 1 MΩ and a nearly logarithmic response covering $1\text{-}10^6$ μV. (Science Abstracts).

465. Yurov, Yu. Ya, "The Influence of Gas Films on Contact Resistance," Electrichestvo 6, 47-50 (June, 1949). In Russian.

Theoretical and experimental investigations show increase of contact resistance due to gas films covering these contacts. Removal of gas films by increasing contact pressure, operation in vacuum, external heating, or heating by electrical current cause fall of contact resistance. Theoretical estimates and test results on a 30Ω carbon pile show close agreement. (Science Abstracts).

466. Zimmerman, J. E., "Measurement of Electrical Resistivity of Bulk Metals," Rev. Sci. Instrum. 32, 402-5 (April, 1961).

Describes a.c. induction methods, in which the specimen is in bulk form, no direct contact to it being required. Theoretical expressions are given for a sphere and for an infinite circular cylinder in a uniform applied a.c. field, and an experimental method is described which is applicable to any shape or applied field configuration (Science Abstracts).

467. Zinke, W. L. and Tepper, C., A Program to Develop a System for the Inspection of Soldered Electrical Joints. Eastman Kodak Co., Final rept. AD-295 679 (28 Dec 62). 108pp.

This inspection system is a refinement of commonly used visual inspection for surface defects of solder joints. By making defects luminous under ultraviolet light, visual inspection becomes more reliable, less time consuming, and less dependent on operator skill and judgement. The system is useful for inspection of soldered joints in any electronic assembly, but particularly applicable to printed circuit construction. It is non-destructive, compatible with any manufacturing rate, and sensitive enough to detect quality trends before obviously defective material is produced. (ASTIA Technical Abstract Bulletin).

468. Newman, I. M., and Albin, A. L., "An Integrated Approach to Bonding, Grounding, and Cable Selection." Proc. 7th Conf. on Radio Interference Reduction and Electronic Compatibility, 434-59 (Nov., 1961).

Several methods to reduce interference are considered. Proper choice of cables, establishment of a ground plane, mechanical and electrical details of bonding are considered in view of the entire system. Multipoint ground systems are usually used because of better radio-frequency interference control. Coupling tests were made on shielded, coaxial, and twisted pair cables at 60 cps power frequency through 29 Mc. radio frequencies. Results are shown, and the magnitude of shielding isolation obtainable is presented. It is concluded that a good ground plane is essential for maximum interference reduction and that shielded, twisted-pair cables offer a satisfactory method for controlling audio and radio frequency interference.

469. Buckley, E. F., "Metal-Foil Shielding Materials and Conductive Mastics for Inexpensive Shielded Enclosures." Symp. Digest, 5th National Symposium on R.F.I. (June 4-5, 1963).

In the design of shielded enclosures, paste and putty-like conductive compounds may be used for more effective joint construction, thus allowing less expensive enclosures to be constructed. Insertion loss usually requiring double-shielding can be realized with these compounds and single-shielding. Shielded enclosures adequate for most purposes can be constructed from existing work rooms using this type of construction.

470. Socolovsky, A., "Surface Physics Looks at Electrical Connections." Electrical Design News 11, 98-102 (Oct., 1963).

Report of a technique developed by the Research Lab. of the Burndy Corp. whereby the effect of constriction resistance on contacts is examined. The contacts are subjected to a current pulse and the fast temperature rise at the interface causes a change in the constriction resistance, which is rapid compared to the change in the bulk material resistance. Relative indications of constriction resistance are thus possible. It is also shown that the constriction resistance is a function of the surface roughness.

471. Ek, Gayne R., "Grounding, Its Part in Practical Circuit Design." E.D.N. Circuit Packaging Reference 12, 15-29 (Oct., 1963).

A review paper in which the author has elected to make the designer aware of problems resulting from a casual consideration of grounding, and point out the techniques and kind of thinking necessary to eliminate such grounding problems. Several examples are used to illustrate proper and improper grounding. The usual problem is feedback or superimposition of signals via inductive, capacitive or common-conductor routes.

472. Ficcki, R. F., "The Grounding of Structures." IEEE Trans. on Aerospace-Support Conf. Procedures, 999-1007 (Aug. 1963).

The general grounding requirements are: (1) Safety, (2) lightning protection, (3) machine protection in case of large current faults, (4) interference reduction. The common methods of establishing and maintaining a suitable ground are presented from a theoretical and practical standpoint. Presents a step-by-step procedure for designing adequate grounding system, primarily based upon the first three general requirements. Gives formula whereby the resistance to earth of various grounding configurations may be calculated.

473. Lightner, D. R. and Toler, J. C., "Implementation of Bonding Practices in Existing Structures." Proc. Eighth Tri-Service Conf. on Electromagnetic Compatibility, 670-89 (Oct. 30 - Nov. 1, 1962)

In reducing electromagnetic interference occurring in test and checkout facilities for space vehicles, the primary concern is an adequate and well defined grounding scheme. This paper presents some of the bonding methods and procedures necessary to acquire such a facility ground. The approach used was to bond all equipments together, forming a large, homogeneous mass, which is connected to earth ground. D. C. resistance measurements are considered to give the most reliable indication of bond quality.

474. Hanson, C. B., "Radio Frequency Impedance Measurements of Nickel-Cadmium Combination Plating on Aluminum Alloy Surfaces for Electrical Bonding, and Anti-Corrosion Finish." Missile and Space Systems Division, Douglas Aircraft Company, Inc., Report No. SM-43482 (March, 1963) AD 299703.

Studies of the radio-frequency impedance of bare metal-to-metal, alodine, and nickel-cadmium finish of bonding surfaces showed that the nickel-cadmium finish was superior to alodine and nearly as good as bare metal-to-metal. A test apparatus was constructed and the impedance determined by voltage measurements across the bond. Data is presented from 0.15 mc. to 100 mc. wherein the impedance of the nickel-cadmium is about 1/10 of the alodine finish and only a few milliohms larger than bare metal-to-metal. Cost of the nickel-cadmium finish is however about 40 times the cost of alodine finish.

475. Blake, K. W., "External Cross-Modulation in the 100 Mc/s Band." J. Instn Elect. Engrs, Pt III A, 94 (No. 14) 659-62 (1947).

An effect observed in ships and appearing as a spurious radiation frequency of 2a - b, where a and b are the frequencies of modulated transmissions. The effect was traced to external cross-modulation arising in parts of the ship's structure, such as foot-ropes and halyard pulley shackles. Location of interference-producing parts was facilitated by the use of a search head provided with tuned loops instead of aerials, so as to operate on the inductive rather than on the radiated field. Two of the loops were fed from 110 and 126 Mc/s transmitters respectively; a third picked up the resulting cross-modulation at 142 Mc/s. (Science Abstracts)

476. Halverson, H., "Testing Microwave Transmission Lines Using the Sampling Oscilloscope," Electronics 34, 86-88 (June 30, 1961).

477. Ehrreich, J. E., "Plastic RF Shielding Forms Based on a New Conductive Filler," Symp. Digest, 5th National Symposium on R.F.I. (June 4-5, 1963).

III. DISCUSSION

In conducting the literature search a large number of articles were uncovered which were not directly related to the program objectives. For example, the literature relating to relay contacts is quite extensive but the majority of the reported work concerns studies and results that have no direct application to the bond measurement problem. Because of their redundancy, irrelevance, or volume, most of these references were excluded from the Bibliography.

A number of additional articles were examined whose value to the objectives of the search was considered marginal. However, most of these references are listed in the Bibliography in the hope that they may be of use in a broader study of contact and bond characteristics.

The residue of the search, which represented those articles directly related to the effort, were, in addition to being included in the Bibliography, subjected to a careful review. Pertinent information extracted from these sources is discussed in terms of applicability to electrical conductivity of bonds in the following sections.

A. Conventional Measurement Techniques

A large percentage of the material studied was primarily concerned with the measurement of direct current resistance. Most of these resistance measurements were made using some form of a four-terminal bridge. In a four-terminal bridge, separate voltage and current connections to the unknown resistance are provided. If the bridge is a potentiometer type, no current flows through the connection between the bridge and unknown resistance. Consequently, to a first approximation, the connection resistance does not affect the results. Other measurements were made by passing a known current

through the bond in question and measuring the voltage across the bond; resistance was then calculated by Ohm's law.

Impedance in general consists of three components—resistance, inductive reactance, and capacitive reactance. The magnitude of the impedance, being the vector sum of the three components, must be carefully interpreted. As frequency changes, the magnitude of the impedance is expected to change since the resistance changes some due to skin effect and the inductive and capacitive reactances are direct and inverse functions of frequency, respectively. Information on the magnitude only of impedance can be misleading since it gives no information about relative values of resistance or reactance. Without some knowledge of resistance and reactance individually, one cannot predict the variation of impedance with frequency; conversely, the variation of the magnitude of impedance with frequency does not furnish unambiguous information on changes in resistance or reactance. The articles examined in this search which reported impedance measurements usually reported only magnitudes of the impedance and not phase angles or magnitudes of resistive or reactive components.

In the literature examined, the usual methods of measuring impedance were:

(1) Voltmeter-ammeter[344,474] method in which a known current is passed through the bond and the voltage developed across the bond is measured, thus allowing calculation of the impedance magnitude. It is very difficult to separate the components of the impedance by this measuring technique.

(2) Insertion-loss technique[6,9] whereby the transmission of a known system is measured with and without an unknown element in the system. The loss caused by the insertion of the unknown can then be related to the magnitude of the impedance of the unknown. If, in addition, one measures the phase shift caused by insertion of the unknown, the impedance can then be separated into its components.

(3) "Q" measurements[9,436] wherein the unknown is made part of a resonant circuit or cavity. The measured circuit "Q" may be related to the impedance of the circuit components, one of which is the unknown. This method was used to find the resistive component of the impedance of the unknown element on the assumption that the effects of the reactive components were negligible compared to those of the original circuit.

(4) Four-terminal bridges[138,181,343] or Kelvin double bridges which pass the current through the unknown via one path, utilize separate connections for determining the potential across the unknown. This arrangement is used to reduce the mutual impedances appearing in the current and potential measuring circuits. Mutual impedances exist because the bond or unknown has finite dimensions, and connections to the unknown cannot be made in such a way that the impedance of some of the bulk material is not also included in the measurements. This bulk material impedance can be considered as mutual impedance since it is common to both the current and potential circuits.

(5) High frequency bridges of various types, usually having a resistance and a reactance balance. Due to connection methods and other factors, the lower limit of this type instrument is usually a few ohms. Such instruments, however, permit the components of the unknown impedance to be resolved.

Data were reported for impedance magnitude measurements over a frequency range from direct current to about 400 Mc. The larger part of the data was for direct current or power frequency (60 - 400 cps) measurements. Resistances were measured from a few microhms for aluminum and copper busbar joints to complete open circuits. Some data on radio frequency bond measurements[6] show impedance variations of about 160:1 over a frequency range of 200:1. These

data are not conclusive when it is recognized that the reactance is a function of the frequency. The author assumed the impedance was primarily inductive in nature; it is seen from the data, however, that some capacitance was also present. Albin[5] shows impedance can increase approximately 100 times as frequency is changed from direct current to 3 Mc for certain samples. These results do not show the relative change in the resistance and reactive components. Wellard,[436] using a specially constructed tuned coaxial cavity, indicates that data accurate to about 5 per cent up to 400 Mc can be obtained for resistance measurements. This method requires special laboratory apparatus and precise readings. Since the unknown resistance must conform to a specific configuration, this technique is not a general solution to impedance measurement requirements.

The Kelvin double bridge or a modification of this circuit[138] seems to have the best accuracy for low resistance measurements at direct current and power frequencies. The insertion-loss technique is said to be usable up to about 30 Mc with conventional equipments and up to thousands of megacycles with suitable coaxial or waveguide equipment. However, insertion-loss methods are not usually suitable for very low impedance measurements at these high frequencies, because the test sample must exhibit a configuration that is compatible with the equipment being used and because connection impedances to the unknown can cause serious errors. The simpler and more direct voltmeter-ammeter method is useful at direct current and through a few megacycles. At much higher frequencies measurements become inaccurate because of poor sensitivity and standing wave effects. As the frequency increases, the length of the voltmeter leads may exceed the wave length of the signal under consideration. Under these conditions the voltmeter leads act as an improperly terminated transmission line. The resultant standing waves can produce

significant errors in the voltmeter reading. It can be shown that, depending upon the type of voltmeter circuitry, the meter may indicate any value between zero and a value somewhat above the actual voltage across the bond. Obviously, unless very careful precautions are taken, serious errors are likely to result from voltmeter-ammeter measurements at very high frequencies.

Of all the methods of measuring impedance that were examined, the four-terminal bridge arrangement appears to be the most accurate provided direct current or low frequency(power) measurements are sufficient. Up to a few megacycles the voltmeter-ammeter method appears to be the easier method to use. The literature indicates that above a few megacycles low impedance measurements are of doubtful validity,[330] even under laboratory conditions. There seems to be no really practical way to measure a very low impedance of general configuration at high frequencies at the present time.

B. Instrument Connection Impedance

Conventional measurement techniques which require an electrical connection to the bond test sample obviously introduce errors which are a function of the connection impedance. The connections are in fact additional bonds which normally exhibit impedances of the same order of magnitude as the bond under test. Consequently, careful consideration must be given to techniques whereby this source of error can be negated.

Pullen[343] has stated that for conventional measurement techniques the resistance between connections of finite cross section cannot, in principle, be separated from the resistance of the whole system. This can be seen since physical connection of the measuring apparatus must of necessity be a finite distance from the element whose resistance is desired; thus additional resistance will be measured. This problem becomes significant when the area of contact is

comparable to the area of the conductors. Holm[213] gives data on an experiment in which the problem was so severe that the measured value of the resistance was negative.

Graff et al,[181] Fairweather et al,[138] and Pullen,[343] having recognized this problem, used a form of the four-terminal Kelvin double bridge, either at direct current or at low frequencies. This type of bridge arrangement effectively removes the connection resistance from the measurement, since the potential measuring circuit requires no current at balance and thus the resistance of the bridge arm in series with the connection resistance can be made so large that the connection resistance is negligible in comparison. Accuracy is very good at low frequencies but the arrangement is limited to low frequency measurements. An upper frequency limit is imposed by standing wave effects and by inductive coupling between the current and potential leads. Inductive coupling is present because the magnetic field produced by the current through the bond passes through the potential measuring circuit loop, introducing unwanted voltage into this loop.

In making bond impedance measurements by the insertion-loss technique, at frequencies up to 30 Mc, Allen,[6] noted that the length of the connection element became a large source of error when its inductive reactance became large compared to the impedance of the bond. Reducing the connection length to the smallest value possible for the given setup still resulted in about 20 per cent difference in measured and calculated values. This type of error (connection-length impedance) is inherent in most measuring techniques. In the insertion-loss method used by Allen[6] a relatively large voltage drop occurred across this connection impedance when the unknown (bond) was inserted; thus the measured value included this connection impedance (essentially inductive at the frequencies used) and was not a true indication.

Data on magnitude of bond impedances obtained with the voltmeter-ammeter method[344] were consistent up to about 15 Mc. A more recent report,[474] presents measurements made by the voltmeter-ammeter method up to 100 Mc. It must be noted that voltmeter-ammeter measurements give only the impedance magnitude and do not indicate the actual components of the impedance. The references noted (344,474) used specially constructed apparatus and carefully prepared samples; their data are not necessarily indicative of results which would be obtained with other configurations. As pointed out in Section III A, voltmeter-ammeter techniques are limited at higher frequencies by standing wave effects.

Slotted waveguide and coaxial cavity methods[9,436] are useful at microwave frequencies, but these methods usually are limited to laboratory investigations because of the requirements for special apparatus and special sample configurations. Errors due to the connection impedance are comparable to the unknown impedance.

Due to the complexity and possible errors in measurements at higher frequencies, at least one source[473] concludes that direct current resistance measurements probably are the most reliable method of evaluating bond connections at the present time.

C. Special Measurement Techniques

Literature reports on the evaluation of the electrical characteristics of bonds or contacts usually show that this information is obtained from the employment of well known techniques of either voltage drop or bridge measurements. Although these techniques have a sound basis in theory, their implementation in currently used measuring devices has limited evaluation of bond impedance to a narrow frequency range. Most of the interest has been

in the study and measurement of direct current resistance. This resistance is often taken to represent the significant electrical property of a bond. Experience with radio frequency interference has shown, however, that knowledge of the total impedance of a bond is essential in classifying its quality.

The intent of this particular section is to report on a phase of the literature survey directed toward discovering new techniques or fresh approaches that are not commonly associated with bond evaluation. Activities in different fields of work such as acoustics, heat transfer, radio frequency leakage and pulse techniques were reviewed.

Several sources report studies of the effects of mechanical vibrations on the resistance characteristics of contacts and welds. Direct currents or low frequency alternating currents were the principal types of excitation used. Significant work was done by Cherry[76] in the investigation of the dynamic resistance of spot welds by observing the variation in direct current flowing through a joint while it was being mechanically excited.

No work was reported on observation of cases where radio frequency energy was flowing through a joint undergoing mechanical vibrations. It would be expected from an extension of Cherry's work that modulation of the radio frequency currents could be related to the impedance of a joint.

Measurement of thermal conductivity through a metallic joint has been reported by several investigators. One phase of the work reported by Holm[213] was the evaluation of the resistance of a static contact by relation to the thermal conductivity through the contact. A direct current was passed through the contact and the resulting temperature rise of the material in the immediate vicinity was measured. Comparison of the known thermal conductivity of the bulk

material with that determined from the experiment was the basis for evaluating the resistance of the joint. No reports of utilization of high frequency currents in this type of experiment were found among the sources reviewed. The substitution of radio frequency energy for direct current energy in these experiments appears feasible. This addition to the technique should reveal the change in contact resistance between the direct current and radio frequency conditions.

Use was also made of thermal characteristics in Holm's investigations, to determine the relative areas of actual electrical contact to the apparent contact surface. From this kind of information the physical surface characteristics of the joint may be derived. Utilization of this type of information can be applied to the calculation of electrical parameters or impedance characteristics of a joint.

A radio frequency leakage technique has been treated by Albin[5] in which bonding impedance magnitude, as measured by the voltage drop method, was compared with the shielding efficiency. Shielding efficiency was the actual attenuation in db experienced by the energy in a path from one edge of a joint boundary to the other. The characteristic of the measured joint impedance was compared to the characteristic of shielding efficiency over a similar frequency range and, in general, this comparison showed an inverse relationship. Whether or not this was expected was not stated. Measuring shielding efficiency was accomplished by using a search probe antenna to detect leakage. Energy on one side of the boundary was injected by a loop antenna which illuminated the region in the vicinity of the joint. The joint was a part of the junction between a box enclosure and its lid. The radiating antenna was placed inside the box. No statement was made about conductive

injection of the electrical energy into the system by connection of the feed system to each side of the joint boundary. It would be expected that this arrangement might show the frequency characteristic of the shielding efficiency to be directly proportional to the impedance characteristic measured by the voltage drop method.

An observation of the characteristics of measured impedance showed a greater relative change with frequency than did the shielding efficiency characteristic. Albin concluded that a difference of 2 to 1 in measured bonding impedance frequently represented a change of 10 or 100 to 1 in shielding efficiency.

Halverson[476] describes a pulse reflection technique in the measurement of impedance variations on high frequency coaxial cable. He states that a pulse reflection technique can be used to give a direct reading of characteristic impedance on lines as short as one foot to within a few tenths of an ohm. This technique permits identification and reasonably good measurement of the two types of reactance encountered. This system consists essentially of a step function or fast rise pulse-generator and a sampling oscilloscope. His particular pulse source contained frequencies up to about 350 Mc and he points out that determining the exact magnitude of these frequencies would require careful analysis of the waveform. The magnitude of each of these frequencies, reflected from a specific reactive discontinuity, would also take careful analysis. He was able to calibrate his system by standard discontinuities and provide a direct reading of impedance of 1 ohm per centimeter of deflection on the sampling oscilloscope. Halverson's technique appears very promising if it can be properly applied to measurement of joints of any configuration.

Hitchcox[210] describes some resistance measuring circuits using direct and

alternating test currents. One of these is a novel instrument which can measure very low resistance using pulsed test currents. A periodic train of triangular pulse currents is applied to the specimen under test and a voltage is derived which is proportional to the resistance of the specimen. Peak currents greater than 500 amperes were used in his system to provide signals large enough for reliable detection and measurement. The noise voltage in this circuit was said to be about 50 microvolts. The pulses were about one millisecond long and occurred at the rate of 10 pulses per second. With this low duty cycle only a fraction of a watt is dissipated in a resistance of only one microhm. Triangular pulses were used in this case to minimize inductive effects.

His equivalent circuit for the test specimen is an inductance in series with a resistance. Therefore the mathematical treatment of this technique would include a voltage term arising from the inductive reactance of the system. By using a differentiating network in the circuit the inductive term drops out.

Assume the test current follows the law,

$$i = At,$$

where A describes the waveform characteristic. Then the voltage across the test sample is

$$v = Ri + L\, di/dt,$$

$$= R\, At + L\, A,$$

since $(\frac{d}{dt})i = A$.

When this signal is fed to a differentiating network the output of the

network will be

$$v_o = B\, dv/dt = BRA,$$

where B is the factor relating to the characteristic of the differentiating network. His only application of this device was the measurement of the resistive component of the specimen. The mention of the use of other types of waveforms pointed out the effect of inductance that in his application was detrimental. The fact that this component of the impedance of a test sample was recognized suggests possible utilization of this technique in measurement of the total impedance of a joint.

In reviewing the different special measurement techniques that have possible application to evaluation of bonding impedance it appears that pulse techniques offer greatest promise of utilization. The other techniques are attractive in varying degrees at the present time. Their usefulness appears to be greatest, however, in the role of supplementary aids to the common type measurement techniques.

Pulse techniques are attractive principally because of the wide frequency spectrum contained in the excitation signal used. If magnitude and phase measurements of impedance are possible over a wide frequency range then these techniques provide rapid means for complete evaluation of the electrical properties of bonds.

D. Physical and Chemical Factors

Although the effect of various chemical and physical factors on the impedance between metal surfaces in contact has not been the subject of extensive investigation, a considerable amount of work has been done on the effect of such variables on contact resistance. We will first briefly review

some of the more recent work on the latter topic.

Contact resistance may be considered to consist of two parts: the constriction or spreading resistance, and the film or interface resistance. The constriction resistance arises from the fact that two surfaces in apparent contact touch only at a few spots, the area of which constitutes a small fraction of the apparent area. The charge can flow from one metal to the other only at these points of contact and the flow pattern of the charge within the metals near the boundary must change. This change in the flow pattern increases the length of the path followed by the charge and decreases the effective area of the conductor; either effect results in an additional resistance. Thus, the constriction resistance is an additional resistance within the metals resulting from the nonuniform flow of current in the body of the materials.

True metallic electrical contact between the bulk metals may be prevented even at the areas of mechanical contact by poorly conducting films of oxides or other extraneous material; this leads to the second component of contact resistance—the film resistance.

The reduction of contact resistance requires the establishment of metallic contact over as large an area as possible. Schreiber[383] suggests that a material having the following properties should have low contact resistance:

a) low resistivity

b) soft

c) either does not form nonconductive films or forms films which are broken under moderate loads.

Holm[213] has discussed many of the physical and chemical factors which affect the bond resistance between metals in contact. Ittner and Magill[230] in

a review article on the contact resistance of nominally clean surfaces list the following factors which affect the resistance between two samples of the same material in contact:

resistivity

applied load

micro-topography of the contact surfaces (i.e., size, shape, and number of contact spots)

modulus of elasticity or hardness

electron work function and thickness of surface films separating the metals, or resistivity of the surface film

lateral motion of the objects in contact

maximum current through the contact surface.

The effect of the mechanical load forcing the contacts together has been investigated in a number of papers (Ittner and Magill;[230] Little and Kouwenhoven;[291] Kouwenhoven and Little;[269] Baimakoff;[30] Wilson;[447] Thompson and Behr;[416] Monashkin;[310] Shackman and Thomas;[387] Bailey;[28] Compton and Baker[89]). In general, contact resistance decreases with the applied load. The decrease in resistance is also dependent on the materials in contact because the load-bearing area is a function of the load and the mechanical properties of the materials.[5,203]

Kouwenhoven and Sackett[270] have shown that the number, shape, and location of the actual conducting spots between two materials affect the constriction portion of the contact resistance. The resistance decreases as the total area increases but the resistance is lower if this area is divided between several discrete areas rather than being localized in one. An elliptical contact area has a higher conductivity than a round one of the same area. Also, location of the conducting spots off the center of symmetry of the apparent contact area leads to an increase in the resistance of the joint.

Surface preparation affects contact resistance in two ways: by removing or disrupting oxide films which prevent true electrical contact or by changing the number, size, and location of the conducting spots. Fukuroi and Muto[157] investigated the contact resistance between crossed tungsten rods which had been mechanically polished, electrolytically polished, or electrolytically etched. The variation with load was different for the three surface finishes and this was due, at least in part, to varying contributions from the film resistance. Thompson and Behr[416] demonstrated the decrease in contact resistance of copper or aluminum surfaces as a result of filing or scratching with a wire brush. Killian[256] and Rowland[367] have also demonstrated decreases in resistance due to abrasion of the contact surfaces. In addition to the fact that abrasion disrupts the oxide film present on metals such as aluminum it also increases the number of points at which contact is made since, generally, two rough surfaces will make contact at a larger number of positions than will two smooth surfaces. This decreases the contact resistance.

A wiping or sliding action between the two contact surfaces may also reduce the contact resistance.[7,89] Presumably this action disturbs oxide or other poorly-conducting layers on the metals.

The value of various joint compounds in establishing and maintaining low resistance bonds has been the subject of several investigations. These compounds have most often been associated with joints in which at least one of the metals is aluminum. They serve usually to remove oxide films on the metals or to prevent the films reforming when they have been broken. Bonwitt,[49] Thompson and Behr,[416] Shackman and Thomas,[387] and others have studied various compounds.

Another method of reducing contact resistance is by plating one or both of the metals. A properly applied plating should have essentially no contact resistance to the bulk material; that is, it should represent simply an extension of the bulk material. The contact resistance is then the resistance between the plating materials, and these may be chosen specifically to reduce contact resistance whereas the bulk materials must be chosen with other considerations in mind. The value of plating has been discussed by Bonwitt,[49] Burley,[65] Conner and Wilson,[92] Pearlston,[330] Compton and Baker,[89] and Bailey.[28]

Although the temperature at a contact surface is itself not a fundamental property, a number of authors, for example, Williamson,[444] have emphasized its importance as an indication of the quality and probable stability of the contact. A close relationship exists between the temperature rise of a contact and the current through it.

A recent report[474] compares impedance measurements over the frequency range 150 kc to 100 Mc for aluminum surfaces which were bare and clean or were alodine coated or were nickel-cadmium plated. The contact impedance at constant applied force between bare surfaces was lowest, the nickel-cadmium plated surfaces having an impedance about twice as large. The alodine coated surfaces had impedances which were 10 to 40 times as large as those of the bare surfaces. The magnitude of impedances of the bare and nickel-cadmium plated surfaces showed a general increase with frequency while the impedance between the alodine coated surfaces was lower at frequencies above 25 Mc than at lower frequencies. The measured values of the impedance were generally in the range 0.1 to 10 milliohms.

Albin[5] measured the magnitudes of the bonding impedances between aluminum or magnesium surfaces at direct current, 150 kc and 3 Mc. The method consisted

of measuring the voltage developed across the bond or across a standard impedance when the two were connected in series with a signal generator. Voltage measurements were made with a radio-frequency voltmeter. Two types of aluminum were tested—types 6061 and 5052 in the Aluminum Association standard designations for wrought alloys. Each type was tested bare and with two different chromate conversion finishes. The direct current resistances of the bonds under the test conditions were generally a few milliohms; the impedances at 3 Mc were hundreds or thousands of times larger. The direct current resistance measurements were more affected by the type of aluminum than by the type of surface treatment; at 3 Mc, however, the surface finish had a larger effect. The magnesium tests were performed between bare surfaces or between surfaces treated by one of three different procedures. The experimental arrangement was unlike that for the aluminum measurements and resistance or impedance values are not comparable. However, the contact resistance values were lower by a factor of 15 to 30 for the bare surfaces than for the treated surfaces. At 3 Mc, however, the surface effect was much smaller and the differences were less than a factor of 2. At 3 Mc, the impedances were a few ohms in value. Albin[5] noted that tests of bonding impedance, either direct current or radio-frequency up to 3 Mc, were not sensitive enough to distinguish between good and poor shielding efficiencies; that is, the shielding efficiency was a more sensitive indication of differences between bonds than was bond impedance.

A review paper by Pearlston[330] surveys bonding and grounding techniques as well as shielding techniques from the point of view of control of electromagnetic interference. He points out that there is little correlation between contact resistance of a bond and its radio-frequency impedance.

The available information on the effect of chemical and physical factors on impedance of bonds is quite limited. Impedance values obtained in two different experimental arrangements are less likely to be comparable than values of the contact resistance obtained in different experiments. Effects of bonding force, contact area, surface films and numerous other variables on the direct current contact resistance have been investigated and are relatively well understood; much of this work must be repeated at higher frequencies.

E. Classification of Good and Poor Bonds

The literature search did not indicate any really satisfactory data upon which a decision could be made as to whether a bond was "good" or "bad." Roullier[366] and also Bailey[28] have used a figure of merit for a joint:

$$\text{F.M.} = \frac{\text{Resistance of actual joint}}{\text{Resistance of equal length of conductor}}$$

A figure of merit (F.M.) of 1.5 or less was considered to be acceptable. The figure 1.5 is arbitrary but gives reasonable results when applied to aluminum and copper busbar connections for large current applications.

Albin[5] and Fischer[143] consider a direct current bond resistance of 0.0025 ohm satisfactory when constructing shielded enclosures, in all except very severe interference cases.

Pearlston[330] has pointed out that low impedance paths are only possible when the dimensions of the bonded members are small compared to the wave lengths of the frequencies involved. Pearlston[330] and Albin[5] conclude there is little correlation between the direct current resistance of a bond and its radio-frequency impedance. Measurements have been made of the radio-frequency

impedance magnitude of bond straps,[6] but other references[330] have indicated this type of data may not be a reliable indication of the effectiveness of the bond strap in an actual installation. The bond strap is usually inductive in nature and at higher frequencies this inductance in parallel with the capacitance of surrounding equipment structures forms significant circuit configurations. Such parallel circuits have very high impedances at the resonant frequency of the circuit. It can be seen that an apparently good bond might act as a very poor bond under these conditions. Such high impedance bonds can radiate electromagnetic energy[475] and be a possible source of radio-frequency interference.

Albin,[5] using voltmeter methods, has shown that the bonding impedance magnitude of certain magnesium samples may be as low as 10^{-5} ohms at direct current and increase to as much as 2.5 ohms at 3 Mc. Assuming that the impedance is mostly inductive these seem to be reasonable figures; consideration, however, must be given to the desired operating frequency—is the bond satisfactory at this frequency? Data from other sources[6,330] also indicate that the magnitude of the impedance of bond straps increases with frequency.

The data examined do not indicate the bondary between good and poor bonds, but rather implies that such a boundary, if it exists, depends upon the actual application. There is no evidence in the literature examined of any reliable test or laboratory method of classifying quality of bonds at the present time. It is believed the relative quality of a bond is directly related to the particular application and should only be determined with reference to the entire system. Such quality determination is almost sure to be a complex and difficult problem.

F. Ageing Effects of Bond Impedance

Graff et al,[181] in their studies noted that contacts may tend to degrade with time, due to corrosion, stress relaxation, breathing of oxidizing atmosphere, or other factors. This problem can be reduced by mechanical rigidity with adequate contact force and energy storage to maintain these forces over long time periods.

Data presented by Connor and Wilson[92] indicate silver-plated aluminum joints did not increase in resistance during a 6 month cyclic heat test, whereas unplated aluminum joints did. Thompson and Behr[416] measured the resistance of 20 year old aluminum joints and found it to range from 0.5 to 300 microhms, depending upon the surface treatment given when the joint was installed. These data indicate that if the joint can be protected against corrosive atmospheres, resistance changes little with time. Bailey[28] gives data on several methods used to prepare joints so that the effects of corrosive atmospheres may be reduced. It is believed that these or other precautions should be observed in order to insure long time joint stability.

Weedy[433] presents data showing that the interface oxide film between copper contacts has a negative temperature coefficient; thus as the temperature of the contact changes, the contact resistance may actually decrease. The data show that contact resistance tends to settle down to some value as time passes during a current overload. This may indicate a nonlinear contact resistance, depending to some extent upon temperature and/or current through the contact.

The literature studied was mostly concerned with direct current or power frequency resistance and thus does not give much indication of what happens to the impedance at higher frequencies. It is believed that oxidation or corrosion

should be kept to a minimum, since at higher frequencies most of the current flow is along the surface. As time passes and the surface becomes covered with a film, the higher frequency impedance may well change, even become nonlinear. If this nonlinear action does occur, it could be a possible reason for increased susceptibility to radio-frequency interference. Therefore as time passes equipments may fail to meet specifications or even become inoperative.

G. Miscellaneous

The importance of good bonds as one method of reducing radio-frequency interference has been pointed out by Newman and Albin,[468] Pearlston,[330] and several others. Metal-to-metal contact is necessary, and the preferred method of obtaining this contact is welding. Buckley[469] has shown that paste and putty-like conductive compounds are available which can make dramatic improvements in the contact between abutting or overlapping metal parts. The purpose of these compounds is to provide more area for the current flow, thus reducing the impedance. Ehrreich[477] discusses in his paper the properties of conductive plastics with spherical shaped conductive metal fillers. Volume resistivity is as low as 10^{-4} ohm-cm. Conductivity is enhanced by using silver coated metal spheres which produce more consistent contact conditions than do flake type metal fillers. He gives a table of qualitative statements showing the advantage that conductive plastics have over other RF sealing techniques in three categories of seals. He states that in tests on some systems shielding obtained by use of metal filled conductive plastics was 75 to 100 db over the range of 50 kc to 10 Gc. In comparison to metal mesh gaskets conductive plastics are more effective seals in the range of 7 Gc to 8 Gc.

If neither welding nor use of the conductive paste compounds is suitable, the possibility of using gallium alloys[196] or mercury-indium-thallium mixtures[257]

might be considered. These alloys are prepared at room temperature and will harden at or near room temperature. These materials have been used for cold welding electrodes onto semiconductors and were found to provide ohmic contacts. A junction might be prepared with such alloys which would resemble a solder joint but would not require application of heat. Such methods (compounds and alloys) may be of use in some bonding requirements and additional study is indicated along these lines, particularly at higher frequencies.

A possible source of radio-frequency interference which does not seem to have been seriously considered is the nonlinearity of the impedance of bonds. Nonlinear bonds might be due to the presence of oxides or other nonmetallic materials in the bonds. These materials have various properties, relatively unknown, and may be considered to be in parallel with the resistance of the actual metal-to-metal contact path. Due to the skin effect, where high frequency current tends to flow along the surface of the conductors, an appreciable part of the high frequency current may flow through these parallel elements. The nonlinearity of the bond impedance would not generally be discovered as a result of resistance or impedance measurements. Even though the measured values of both the direct current resistance and the high-frequency impedance might be within acceptable limits, indicating a satisfactory bond, the nonlinear impedance might still produce radio-frequency interference.

The interference results from what is commonly referred to as intermodulation and occurs whenever two or more signals of frequency f_a and f_b are applied to a nonlinear device. In essence two effects occur: (1) the nonlinear characteristic causes a distortion of the original signals and produces additional signals harmonically related in frequency to both f_a and f_b,

(2) the original signals and their harmonics are combined or mixed to produce still more signals whose frequencies, f_i, are related to the sum and difference frequencies of any of the original or harmonic signals. In general the relationship may be stated as

$$f_i = nf_a \pm mf_b$$

where n and m are integers.

In practice, the interference susceptibility of an electronic instrument or device is greater than that indicated by the frequency relationship. This results from the fact that most practical devices are sensitive not only to a discrete frequency f_i but to a band of frequencies about f_i. Consequently, any frequency generated in accordance with the above equation and falling within the frequency band $f_i \pm \Delta f$ could cause serious interference provided it is of sufficient signal strength. Fortunately, complete chaos and saturation of the available spectrum is in practice avoided since the magnitude of the signals generated by nonlinear devices generally decreases rapidly with harmonic order. As a result the majority of the new frequencies have magnitudes below the interference susceptibility characteristics of practical equipments. Consider, however, transmitters or other devices having intended outputs of kilowatts or even megawatts at particular frequencies and located in close proximity to susceptible equipments. Even with considerable path and harmonic order attenuation, the susceptible equipment could, via radiation or conduction paths, be subjected to milliwatts or watts of power within some sensitive frequency band, $f_i \pm \Delta f$. Normally, signals of this level are more than sufficient to seriously degrade or negate the desired operation of the susceptible equipment.

At least one serious example of this type of interference has been described in the literature.[475] Energy at two separate frequencies from two transmitting antennas mounted on a wooden test tower was absorbed by metal plates attached to the tower; corroded joints between the plates served as the mixer. Intolerable interference was observed in a receiver tuned to still another frequency whose antenna was attached to the same tower. When the three antennas were attached to a different wooden support incorporating no metal, the antennas could be brought much closer together without any detrimental result. The interference could again be produced, according to the author, by touching two pieces of corroded metal together near the antennas.

Thus a bond which is satisfactory from the point of view of impedance magnitude might be unsatisfactory because of its nonlinearity. In many applications the actual impedance value may be of less importance than the effects of nonlinearity.

Considerable expenditure and effort is currently being applied to the serious nonlinear properties of various components of electronic equipments with little or no effort being directed to similar effects which exist external to the equipment itself. Metallic containment or mounting structures cannot be overlooked as a major source of radio-frequency interference which may result from the mixer action of nonlinear bonds.

IV. CONCLUSIONS AND RECOMMENDATIONS

The literature survey, although comprehensive, uncovered relatively little information which was directly related to the measurement of bond impedance. An evaluation of the survey indicated that it was very unlikely that a satisfactory device for measuring bonding impedance can be devised within present state-of-the-art capabilities which will be applicable over extended frequency ranges and to all configurations of mating surfaces.

The extent of laboratory investigations relating to contact impedance is negligibly small compared to the investigations of direct current contact resistance. Undoubtedly, extensive laboratory work in this area will be required prior to the specification of a technique or construction of a device suitable for providing the required measurement capability. In addition, this basic investigation is desirable and necessary for a complete understanding of bond characteristics or impedance properties.

In view of the apparent lack of correlation between contact impedance and radio-frequency shielding, it is possible that in many situations impedance measurements are of little significance. If one wishes to prevent radio-frequency interference, measurements of shielding efficiency may be easier to perform and may give a more direct indication of the information desired.

It is felt that more work on surface film nonlinearity is in order as higher frequency currents tend to flow along the surface and any resultant mixing action might initiate serious interference characteristics.

Little work has been done concerning the relationships between acoustical or thermal conductivity and electrical conductivity. Investigations are in order concerning these relations. If such relationships can be determined perhaps measurements of acoustical or thermal properties of bonds will indicate

relative bond quality. Infrared techniques may be of use in this effort.

Of the many impedance measurement methods in use, few are useful at high frequencies and low impedances. Different measurement techniques probably will have to be developed if actual bonding impedance values must be determined under these conditions. It is felt that much of the work already done for direct current resistance studies must be repeated for high-frequency impedance in order that a more complete understanding of bonding problems can be obtained. During and following such studies additional techniques probably will be developed.